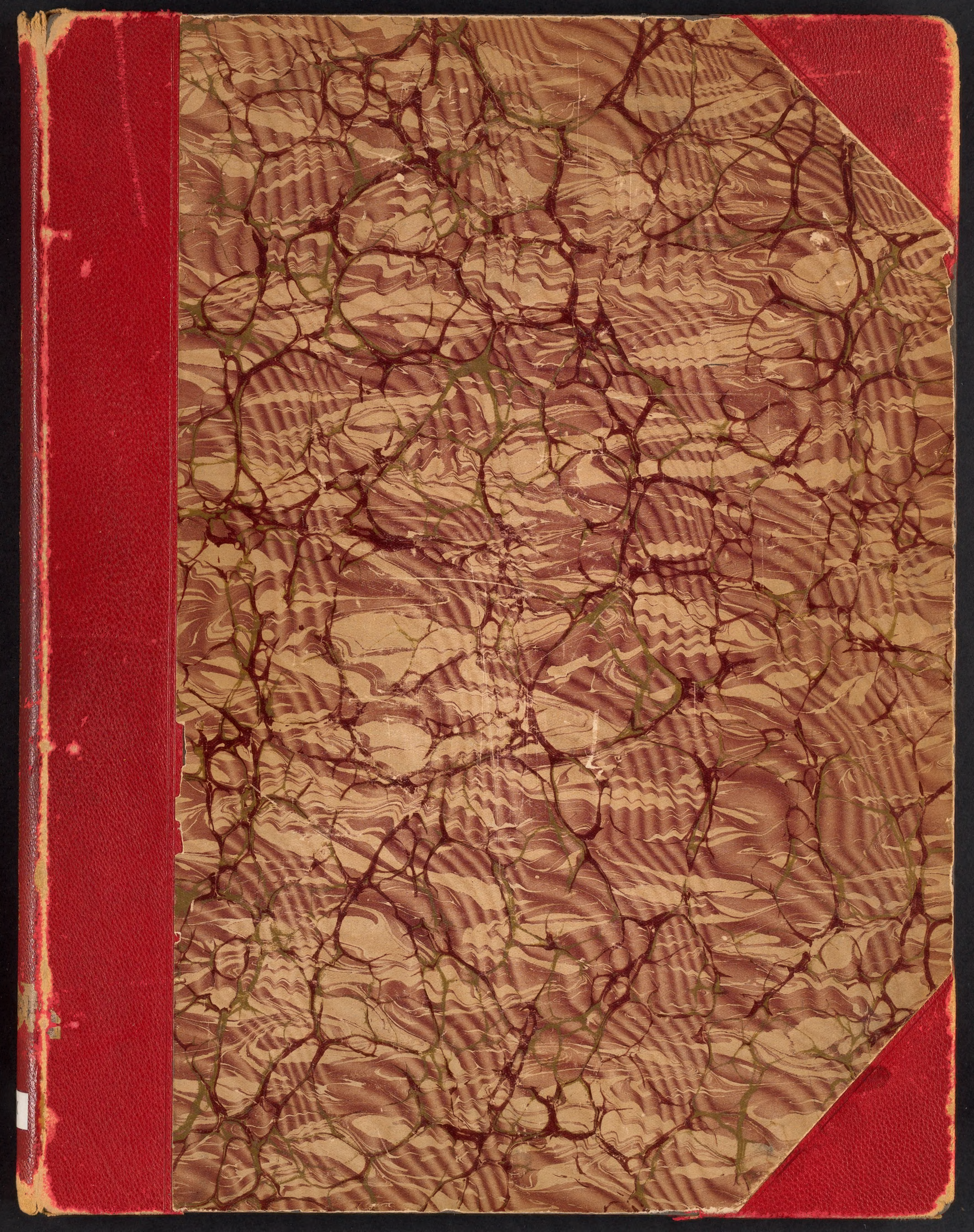
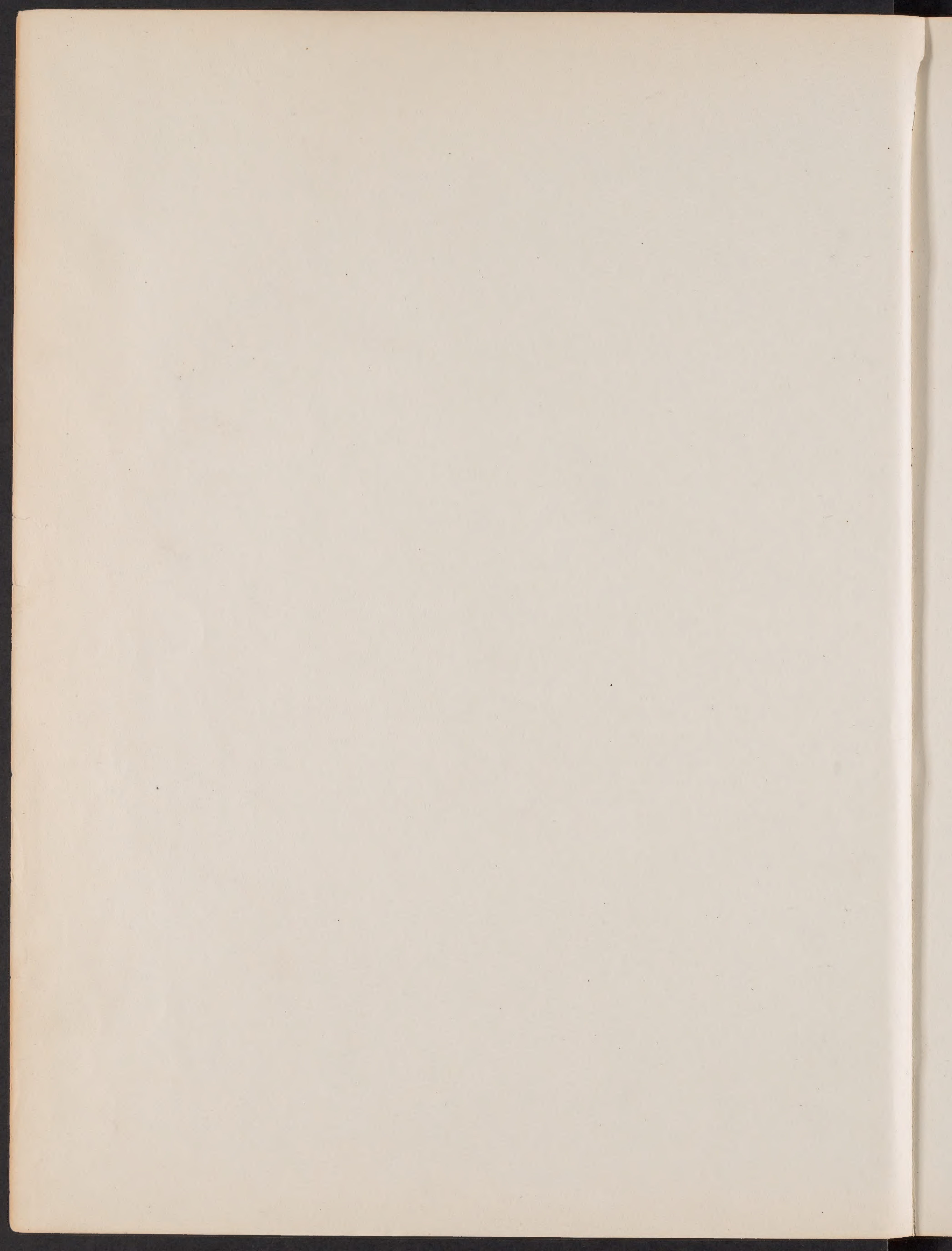
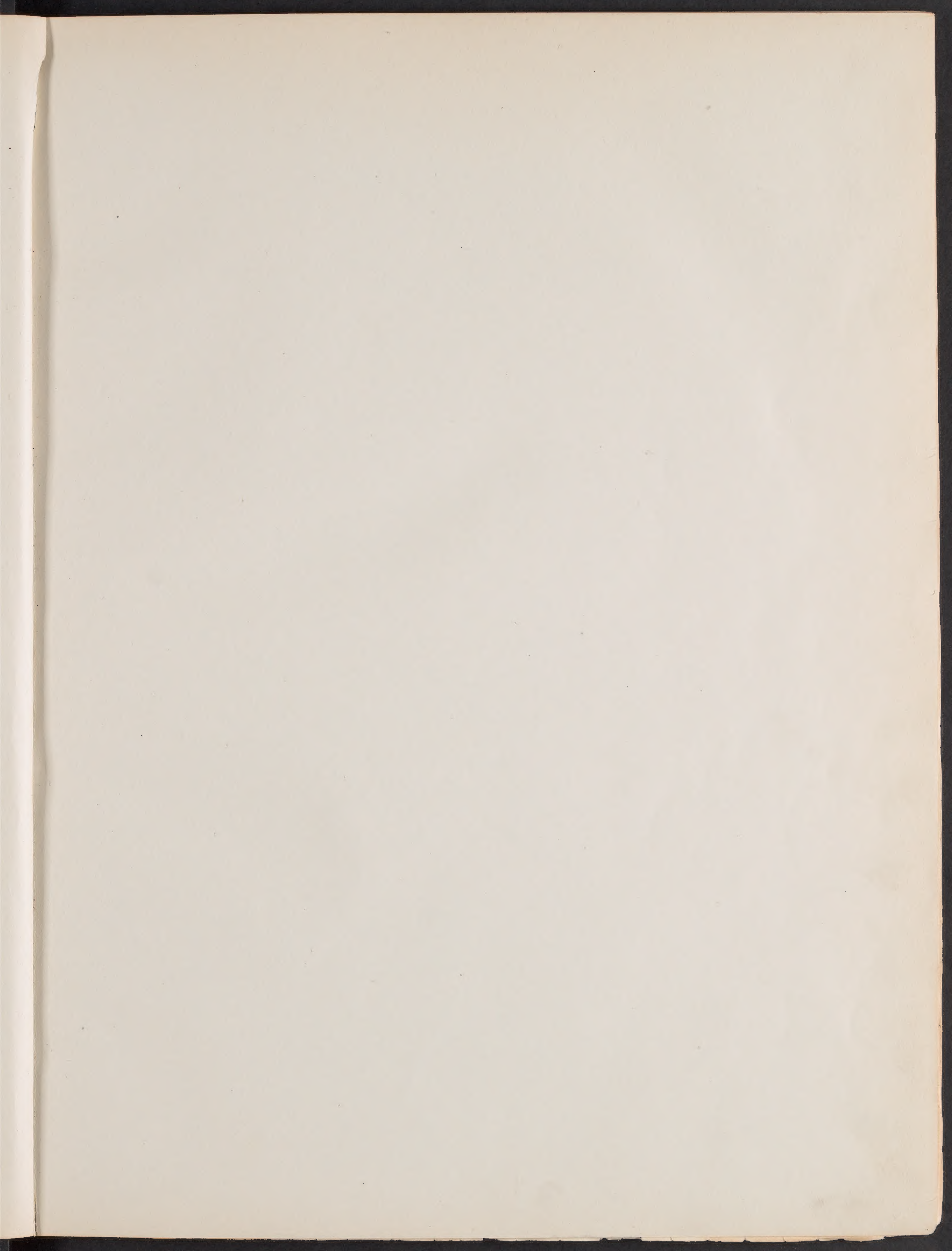








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JENA,
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1911.

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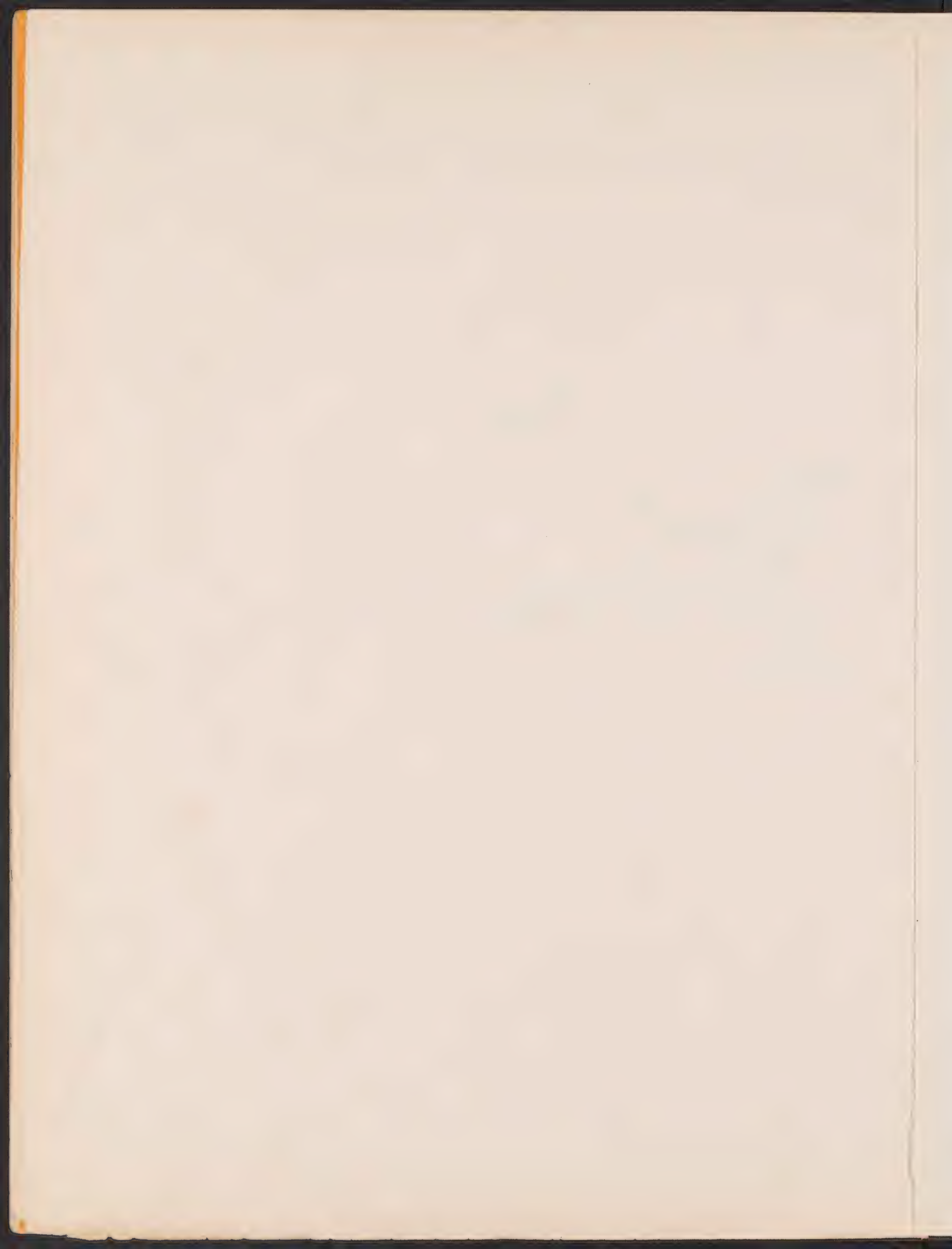
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Contents.



Introduction.

The normal plates of *Acanthias* were undertaken in 1896, when the series was first planned by Professor Keibel. Originally the work was assumed by myself and the late Dr. Alfred Schaper, who was at that time a member of my laboratory staff. I at once proceeded with the collection of the material, the making of drawings and the preparation of the serial sections. As *Squalus acanthias* is abundant on the New England coast, it is caught in large numbers by the fishermen, who are glad to bring the fish in for a small price, as they have no market value. It is therefore possible to obtain during the summer an almost unlimited supply of "candles" as the fishermen call the egg-cases, with ova in all stages of development from segmentation up to those with embryos of about 50 cm. in length.

The drawings were made, with the exception of a few added later, by Dr. Edwin A. Locke of Boston. They are remarkable for their fidelity to the specimens and the beauty of their execution. The importance of the Elasmobranchs for embryological research, since the classic researches of Balfour, has steadily grown. In consideration of their importance it seemed to me be desirable to add to the series of side views, a certain number of dorsal and ventral views of selected stages of our type. To this extension of the programme the editor and publisher have generously consented. I trust that those, who use the plates, will welcome the additional figures.

Dr. Schaper's return to Germany in 1900 precluded his participation in the work and I found myself unable to complete it alone. The matter remained in abeyance until the task was assumed by Dr. Scammon in 1907. Some progress had been made with the bibliography, but he has completed it by considerable labor. His work on the embryos has been based entirely upon the 121 series of sections of *Acanthias* embryos in the Harvard Embryological Collection. The series have not been made at random, but by a carefully followed plan — in general of each stage there are three specimens nearly identical in length and cut respectively in the transverse, sagittal and frontal planes.

The reconstructions of the anatomy of the pig embryo of 12.0 mm. by Professor Frederick T. Lewis, which have been inserted in my Laboratory Text-book of Embryology had demonstrated to us the great value of such pictures. Professor Lewis urged the desirability of adding reconstructions to the normal plates. Dr. Scammon, despite the great amount of work involved, undertook to make them. His success in this laborious task will be appreciated by all who consult the present volume. As the figures were to be in black and white we found it necessary to study carefully all the possible devices for varying the textures, so as to render the various structures perfectly distinct. I think good success has been attained in solving this special technical problem. The pen drawings were made by Mr. W. T. Oliver of Lynn (Massachusetts). The high quality of his work is shown in the figures. It seems to me that the reconstructions enhance the value of the normal plates so greatly, that it is to be hoped they will form an indispensable requirement hereafter.

In conclusion it should be stated clearly that the credit and responsibility for the text and the anatomical reconstructions of this work belong entirely to Dr. Scammon.

Harvard Medical School Boston, Mass.,
October 20, 1910.

Charles S. Minot.

Descriptions of the Embryos figured.

The embryos were in most cases fixed in the corrosive-acetic acid mixture of FLEMMING, although a few specimens were fixed in ZENKER's fluid, in chromo-acetic acid, and in picro-sulphuric acid. In every case the drawings were made from the specimens when preserved in 80% alcohol. Figures 1 to 24b inclusive are drawn at a magnification of eight times the actual size of the specimens. The remaining figures, 25 to 32b inclusive, are drawn at a magnification of five. H.E.C. is an abbreviation for Harvard Embryological Collection.

Fig. 1. Blastoderm, 3.0 mm. in length. Normal plate series No. 1. H.E.C. 986. Dorsal view. × 8.

The blastoderm is elongately oval in outline and bluntly pointed at the posterior end. Its length is 3.0 mm. — its greatest width 1.5 mm. The disc is raised slightly above the surface of the surrounding yolk. The segmentation cavity causes a rounded swelling in the median line, 0.5 mm. from the posterior end. This swelling is approximately 0.3 mm. wide and 0.6 mm. long, with its longer axis placed at right angles to that of the blastoderm.

Fig. 2. Blastoderm, 4.2 mm. in length. Normal plate series No. 2. H.E.C. 989. Dorsal view. × 8.

The blastoderm is broadly oval in outline, a little narrower posteriorly than anteriorly. Its greatest length is 4.2 mm. Its greatest width — a little anterior to the middle of the disc — is 3 mm. The segmentation cavity forms a swelling almost circular in outline and approximately 0.4 mm. in diameter. The margin of this swelling is best defined anteriorly. The posterior margin lies 0.4 mm. anterior to the posterior rim of blastoderm. The posterior margin of the blastoderm is a little thickened near the median line.

Fig. 3. Blastoderm, 4.4 mm. in length. Embryo 0.3 mm. in length. Normal plate series No. 3. H.E.C. 990. Dorsal view. × 8.

The blastoderm is broadly oval in outline. Its greatest length is 4.4 mm.; its greatest width 3 mm. The rim of the blastoderm is thickened around the entire circumference, but the thickening is most marked posteriorly. The embryo appears as a rounded thickening projecting forward in the median line 0.3 mm. from the posterior rim of the blastoderm. The embryonic thickening becomes narrower on either side of the median line and passes over, without distinct lateral boundaries, into the posterior rim of the blastoderm. There is a very shallow indentation, the rim notch, in the posterior edge of the embryonic thickening.

Fig. 4. Embryo 1.4 mm. in length. Normal plate series No. 4. H.E.C. 983. Dorsal view. × 8.

Only a small portion of the blastoderm immediately surrounding the embryo is shown in this figure. The embryo appears as a thickened plate extending forward a little over 1 mm. beyond the thickened rim

of the blastoderm, with which it is continuous posteriorly. The anterior end of the plate is a little expanded — 1 mm. in breadth — and is raised above the level of the blastoderm by the growth of the archenteron below it. A well defined median furrow (the primitive furrow of LOCY) extends forward from the shallow rim notch. The anterior end of the furrow lies 0.4 mm. posterior to the anterior edge of the embryonic plate, and is somewhat expanded.

Fig. 5. Embryo 1.6 mm. in length. Normal plate series No. 5. H.E.C. 988. Dorsal view. × 8.

The medullary plate extends forward 1.0 mm. from the thickened posterior margin of the blastoderm. It is a little broader anteriorly than posteriorly, being slightly constricted where it passes over into the rim of the blastoderm. The edges of the medullary plate are turned a little ventrally. Its greatest breadth is 1.0 mm. The rim notch forms a shallow depression at the median line of the margin of the blastoderm. From the rim notch a deep median groove extends forward for three fifths the length of the medullary plate. The fore-gut forms a broad tongue-like process which extends forward 0.2 mm. beyond the anterior edge of the medullary plate.

In comparison with the preceding embryo of 1.4 mm. the most noticeable features of this embryo are: the expansion of the anterior part of the medullary plate and the projection of the fore-gut swelling beyond it; and the greater differentiation between the medullary plate and the posterior margin of the blastoderm.

Fig. 6. Embryo 1.8 mm. in length. Normal plate series No. 6. H.E.C. 984. Dorsal view. × 8.

The cephalic portion of the medullary plate is somewhat expanded and is raised a little more from the blastoderm than is the posterior part. The greatest breadth of the cephalic portion is 0.7 mm. The edges of the medullary plate are turned a little ventrally. A deep median furrow extends along the posterior five sixths of the plate. It is continuous posteriorly with the broad shallow rim notch. The posterior rim of the blastoderm is much thickened on either side of the rim notch for a distance of 1 mm. These thickened portions project backward a little over the yolk and represent the beginning of the tail swellings. The archenteron forms a broad tongue-like process which projects forward 0.1 mm. beyond the anterior edge of the medullary plate.

As compared with the preceding embryo of 1.6 mm., this embryo shows the following differences: the medullary plate is longer and more slender, and the anterior part (the cephalic plate) is expanded; the rim notch is deeper, and the tail swellings are differentiated from the rim of the blastoderm.

Fig. 7. Embryo 2.0 mm. in length. Normal plate series No. 7. H.E.C. 1009. Dorsal view. × 8.

The cephalic portion of the medullary plate is broadly spatulate in outline and its edges are turned a little ventrally. Its length is 0.8 mm., its greatest breadth 0.6 mm. The boundary between the cephalic and trunk portions of the medullary plate is distinctly marked on the left side. A deep median furrow extends forward from the incisura neurenterica to the middle of the cephalic plate and ends at a low median ridge at this point. The cephalic plate is a little depressed on either side and in front of this ridge. This faint depression probably represents the beginning of the optic vesicles. The trunk part of the medullary plate extends backward from the cephalic expansion as a raised band 0.3 mm. in breadth. The medullary plate becomes indistinguishable from the tail swellings posteriorly. The lateral boundaries

of the archenteron are indicated on either side by a ridge on the blastoderm running outward and backward from the posterior margin of the cephalic plate to the point of union of the tail swellings and the margin of the blastoderm.

When compared with the preceding embryo 1.8 mm. in length, the following differences are noticeable: the medullary plate is raised somewhat more above the surface of the blastoderm; the cephalic plate is expanded to a much greater extent and its boundary is sharply marked; the trunk portion of the medullary plate is longer and narrower than in the smaller embryo; the tail swellings are more clearly marked off from the posterior margin of the blastoderm and, by their extension backward on either side of the median line, form the walls of a distinct canal — the incisura neurenterica; the anterior tongue-like process of the archenteron is covered by the expanded medullary plate.

Fig. 8. Embryo 2.5 mm. in length. Normal plate series No. 8. H.E.C. 1354. Dorsal view. × 8.

The cephalic plate is broadly spatulate in outline and is sharply marked off from the trunk region of the medullary plate posteriorly. It is 0.9 mm. in length, broader before than behind, and has a maximum breadth of 0.6 mm. Its lateral edges are turned a little ventrally. The right edge is indented with four, the left edge with two "neuromeres" of Locy. The optic vesicles appear in the anterior part of the cephalic plate as a pair of depressions which are deep anteriorly and become shallower posteriorly. These depressions are separated by a distinct median ridge. The medullary folds are elevated throughout the trunk portion of the medullary plate. They curve outward rather abruptly on either side of the shallow incisura neurenterica. The tail swellings project backward 0.3 mm. beyond the posterior rim of the blastoderm. The lateral boundary of the posterior part of the archenteron can be traced on the right side only. It extends from the fifth intersegmental cleft to the point of union of the tail swelling and the margin of the blastoderm on that side.

The more important changes shown by this embryo as compared with the preceding one 2.0 mm in length are: the great expansion of the cephalic plate and formation of definite optic vesicles; the elevation of the medullary folds along the entire extent of the medullary plate posterior to the cephalic expansion; the extension of these folds on either side of the incisura neurenterica; and the growth of the tail swellings.

Fig. 9. Embryo 2.7 mm. in length. Normal plate series No. 9. H.E.C. 997. Dorsal view. × 8.

The cephalic plate is broadly oval in outline. Its length is 1.0 mm., its greatest breadth 0.75 mm. The optic vesicles are confluent, forming a deep pit extending from the anterior edge nearly to the middle of the cephalic plate. The greatest width of the pit seen in a direct dorsal view is nearly 0.5 mm. Immediately behind the cephalic expansion the medullary plate is almost flat, but the medullary folds are elevated along the posterior half of the trunk part and extend outward on either side of the incisura neurenterica. The median furrow is seen extending backward from the posterior edge of the optic pit. Posteriorly it is indistinguishable in the floor of the medullary canal. The tail swellings extend 0.4 mm. behind the margin of the blastoderm. They are 1.5 mm. in width at their base. The incisura neurenterica, when seen from above, is broadly V-shaped. It extends inward 0.3 mm. from the tips of the tail swellings. The lateral boundaries of the archenteron appear as faint ridges extending from the narrowest part of the medullary plate to the outer edge of the base of the tail swellings.

The most noticeable advance in development of this embryo as compared with the preceding one of 2.5 mm. is the confluence and deepening of the optic vesicles. The formation of the medullary canal

is not so far advanced in this specimen as in the smaller one. In the larger specimen the tail swellings are somewhat farther differentiated from the blastodermic margin.

Fig. 10. Embryo 3.1 mm. in length. Normal plate series No. 10. H.E.C. 1011. Dorsal view. × 8.

The medullary folds are elevated throughout their extent. They are curved towards the median line only in the posterior half of the trunk portion of the medullary plate. They are least elevated towards the posterior boundary of the cephalic plate. The anterior part of the cephalic expansion is turned ventrally and a little to the right. The optic vesicles form a single deep depression in the cephalic expansion and the vesicle on the left side is seen to be a little invaginated laterally. The tail swellings project abruptly from the posterior rim of the blastoderm and extend backward 0.5 mm. over the yolk.

As compared with the preceding embryo of 2.7 mm., this embryo shows the following changes: the optic vesicles are farther expanded; the edges of the cephalic plate are elevated; the tail swellings are farther differentiated from the blastoderm.

Fig. 11. Embryo 3.2 mm. in length. Normal plate series No. 11. H.E.C. 978. Dorso-lateral view. × 8.

The anterior third of the embryo is separated from the blastoderm. The free part is turned to the right and a little downward. The medullary folds in the head region are curved mesially but there is a large cleft between their free edges. They gradually approach and meet at the tip of the medullary tube. At the posterior limit of the former cephalic plate they approach each other and are in contact, although not fused, for a distance of 0.7 mm. behind this point. Posterior to this closed region the medullary canal widens until at the incisura neurenterica the folds are 0.3 mm. apart. The tail swellings project sharply from the rim of the blastoderm. They are 1.5 mm. in width at the base and extend backward 0.5 mm. over the yolk.

As compared with the preceding embryo of 3.1 mm., the chief advance in development is in the more complete formation of the medullary canal.

Fig. 12. Embryo 3.2 mm. in length. Normal plate series No. 12. H.E.C. 994. Dorsal view. × 8.

The anterior sixth of the embryo is separated from the blastoderm and is turned a little to the left. The medullary folds are elevated and their edges are turned mesially throughout their extent. They are almost in contact just behind the anterior neuropore, and again behind the hindbrain. The optic vesicles are somewhat expanded laterally, although this is not well indicated in the figure. The first gill pouch is seen as a slight swelling on the left side of the embryo, just behind the free cephalic end. Ten pairs of somites are visible externally. On the left side the unsegmented axial mesoderm is seen as a distinct ridge extending backward 0.3 mm. beyond the last somite. The lateral boundaries of the archenteron form prominent ridges extending backward and outward on either side, from the sixth segment to the outer edges of the tail swellings. The tail swellings project backward over the yolk 0.5 mm. beyond the posterior rim of the blastoderm.

This embryo is but little farther advanced than is the preceding one, which is of the same length. The chief evidence of farther development is the appearance of the first gill pouch in the present specimen. The closure of the medullary tube, as a whole, has proceeded somewhat farther, and the incisura neurenterica is covered a little more by the medullary folds.

Fig. 13. Embryo 3.3 mm. in length. Normal plate series No. 13. H.E.C. 980. Dorsal view. × 8.

The head and a little of the anterior part of the trunk of the embryo are free from the blastoderm and are turned to the right. The posterior two thirds of the embryo are unflexed, and are seen in straight dorsal view. The medullary folds meet for a distance of nearly 0.5 mm. in the region of the hindbrain; throughout the remainder of their length they are turned mesially and are almost in contact. The incisura neurenterica is covered in part by the medullary folds. Eleven pairs of somites can be seen externally. The lateral boundaries of the archenteron appear as distinct lines passing from the last pair of somites to the angle formed by the tail swellings and the posterior rim of the blastoderm. The tail swellings project backward over the yolk for 0.5 mm. Their lateral edges meet the posterior rim of the blastoderm nearly at right angles.

As compared with the preceding embryo of 3.2 mm., this embryo of 3.3 mm. shows the following changes; the embryo is separated a little more from the blastoderm; the medullary folds are much higher and have fused over a small part of the medullary canal; the archenteron is reduced in width posteriorly, as is indicated by the position of the ridges formed by its lateral boundaries; the tail swellings are narrower, longer, and they join with the blastoderm at a more acute angle.

Fig. 14. Embryo 3.5 mm. in length. Normal plate series No. 14. H.E.C. 982. Dorsal view. × 8.

The head and a little of the pharyngeal region are separated from the blastoderm. The medullary folds are in contact, or nearly so, throughout their extent, except over the incisura neurenterica and at the anterior neuropore. Only the posterior end of the latter opening can be seen in the figure. The right optic vesicle appears as a very slight protuberance from that side of the head. Just behind this, and separated from it by a slight depression, is a faint elevation caused by the first gill-pouch. Only nine pairs of somites are shown in the illustration, although fifteen pairs can be counted in the sectioned embryo. The incisura neurenterica is covered in part laterally by the medullary folds, but still appears as a deep V-shaped opening when seen from above.

As compared with the preceding embryo of 3.3 mm., the most noticeable advances in development shown by this specimen are the separation of the head from the blastoderm, and the partial enclosure of the incisura neurenterica.

Fig. 15. Embryo of 3.25 mm. Normal plate series No. 15. H.E.C. 1499. Lateral view. × 8.

The embryo lies with the left side toward the blastoderm. The head and pharyngal regions are raised and free from the extra-embryonic disc. The medullary folds of the head region are in contact, except at the anterior neuropore and over the hind-brain. The optic vesicle forms a prominent hemispherical protuberance from the side of the head. Posterior to the optic vesicle is a slight swelling caused by the first gill pouch. The anterior mesoderm forms a faint ridge continuous behind with the somite ridge and extending forward to the optic vesicle. Fifteen pairs of somites are visible externally. The coelom is dilated and its walls are semi-transparent. The medullary canal is closed throughout the trunk region, and the incisura neurenterica is to a large measure enclosed.

The more noticeable points of difference between this and the preceding embryo are: the bending of the head and separation of the anterior part of the embryo from the blastoderm; the increase in number of somites from ten to fifteen pairs; and the advance in the process of closure of the medullary tube and incisura neurenterica.

Fig. 16. Embryo of 4.0 mm. Normal plate series No. 16. H.E.C. 930. Lateral view. × 8.

The embryo lies with the left side toward the blastoderm. The head is bent at a little more than right angles to the body. The anterior fourth of the embryo is free from the blastoderm. The optic vesicle forms a prominent projection from the side of the fore-brain. The medullary canal is closed completely, except for a small neuropore. The premandibular somite forms a prominent oval swelling above the optic vesicle. The first and second gill pouches are indicated externally by oval swellings in the pharyngeal region. The first pouch is a little more prominent than the second. Seventeen somites are visible externally. The tail is free from the blastoderm for 0.5 mm. or one eighth of the length of the embryo.

The most striking change between this and the preceding embryo is the complete closure of the incisura neurenterica and the separation of the tail from the posterior rim of the blastoderm. The head is bent at a much greater angle with the body, and the medullary folds are now fused over the hind-brain. The premandibular somite is much enlarged. A second gill pouch has appeared and the first gill pouch is more prominent.

Fig. 17. Embryo of 3.8 mm. Normal plate series No. 17. H.E.C. 1498. Lateral view. × 8.

The embryo lies with the right side toward the observer. The anterior two-fifths and the posterior one-fifth are separated from the blastoderm. The dorsal back line is a little concave. The pharyngeal region and tail are bent somewhat ventrally from the back. The head is bent ventrally from the pharyngeal region at an angle of 45°. The optic vesicle forms a prominent oval elevation, the center of which is slightly depressed. The otic plate is a little depressed. The mandibular somite appears as a prominent wedge-shaped swelling above and a little behind the optic vesicle. It can be followed down the entire length of the mandibular arch. The trigeminal nerve crest forms a broad plate lying dorsal to the mandibular somite and the first gill cleft. The facial nerve crest forms a distinct ridge extending from the hind-brain to the middle of the hyoid arch. Behind the facial crest the glossopharyngeal-vagus crest appears as a small raised triangle over the side of the hind-brain.

The first and second gill slits are seen as oval thickenings, each of which is depressed centrally. The first gill cleft is nearly twice the length of the second. The heart appears as a rather indistinct straight tube lying in front of the anterior wall of the yolk stalk. Twenty-eight somites can be counted externally. The Wolffian duct forms a small ridge lying below the seventh, eighth, and ninth somites.

As compared with the preceding embryo the noticeable features are: the further separation of the embryo from the blastodisk; the prominence of the nerve crests and gill clefts in the head region; the increase in number of somites visible externally; and the appearance of the Wolffian duct.

Fig. 18. Embryo 4.8 mm. in length. Normal plate series No. 18. H.E.C. 1398. Lateral view. × 8.

The embryo lies with the left side towards the blastoderm. It is connected with the blastoderm for a little more than its middle third. There is a distinct dorsal flexure above the attached portion of the embryo. The head is bent at an angle of 60° to the pharyngeal region. The tail is bent slightly ventrally. A very faint depression marks the line of division between the fore-brain and mid-brain. The optic vesicle forms an oval protuberance from the fore-brain; this protuberance is depressed centrally. The outline of the trigeminal nerve crest, with its thalamic and mandibular branches, can be seen above the optic vesicle. The facial nerve crest forms a prominent ridge extending from the dorsal zone of the hind-brain nearly to the base of the hyoid arch. The otic pit appears as a shallow depression posterior to the upper part of

this ridge. The glossopharyngeal-vagus nerve crest forms a faintly outlined triangular plate just posterior to the otic pit. There are distinct elongately oval plates over the first and second gill pouches. The gill clefts appear as narrow grooves in these plates. The ventral wall of the oesophagus and the anterior wall of the yolk stalk form a continuous curved line extending from the posterior end of the pharynx to the blastoderm. The heart appears as a faintly outlined straight tube lying below the anterior part of this line. Thirty somites are visible. The unsegmented axial mesoderm forms a ridge extending from the last somite nearly to the tip of the tail. A similar ridge extends forward from the first somite to the anterior edge of the otic pit. The Wolffian duct appears as a small ridge, 0.5 mm. in length, lying just ventral to the seventh to eleventh segments, inclusive.

The more important changes in this embryo of 4.8 mm., as compared with the preceding one of 3.8 mm., are the following: the head and tail regions have become straightened until more nearly in line with the trunk; a marked dorsal flexure is present; the cephalic nerve crests are more prominent and a shallow otic pit is present; the gill clefts are more prominent; the number of somites visible externally is increased by two.

Fig. 19. Embryo 5.8 mm. in length. Normal plate series No. 19. H.E.C. 1497. Lateral view. × 8.

The embryo lies with the right side towards the blastoderm. The connecting stalk between the embryo and blastoderm has an antero-posterior diameter of 2.5 mm. The dorsal flexure is pronounced. The head is bent ventrally nearly at right angles to the trunk. The tail is bent but little ventrally. The optic vesicle is prominent and broadly oval in outline. There is a shallow groove separating the fore-brain from the hind-brain. The roof of the hind-brain is thin and translucent. The outline of the trigeminal nerve crest proper cannot be distinguished, but the boundaries of the thalamic and mandibular branches are faintly visible. The facial and glossopharyngeal nerve crests appear as prominent ridges extending from the dorsal zone of the hind-brain into their respective arches. The vagus crest forms an ill-defined triangular plate, separated anteriorly from the glossopharyngeal crest by a distinct groove. The otic pit is broadly oval in outline: it is deepest dorsally and anteriorly. There are three distinct gill clefts, none of which are broken through. The first gill cleft is almost twice the length of the third. The outline of the heart can be seen indistinctly through the translucent pericardium. Thirty-five or -six somites are visible externally. The Wolffian duct is seen as a faint ridge below the eleventh to sixteenth somites inclusive. There is a distinct median ridge extending around the tail.

As compared with the preceding embryo 4.8 mm. in length, this specimen shows the following differences: the fore-brain and optic vesicles are more expanded; the pharyngeal region is longer and narrower; the third gill cleft is present; the otic pit is deeper; the glossopharyngeal crest forms a ridge distinct from that of the vagus crest; the dorsal flexure is more pronounced; the number of somites is increased by five or six.

Figs. 20, 20a, 20b. Embryo 5.2 mm. in length. Normal plate series No. 20. H.E.C. 1355. Lateral, dorsal and ventral views. × 8.

The embryo has been detached from the blastoderm, and is seen in Fig. 20 from the left side. The yolk stalk has an antero-posterior diameter of 1.7 mm. There is a decided dorsal flexure over the yolk stalk. The head is bent nearly at right angles to the body, and the tail has the stiff curve which seems characteristic of embryos about this age. The optic vesicles are oval in outline when seen from the side, and almost semicircular when seen from above or below. Above them is seen a shallow groove separating

the mid- and fore-brain vesicles. The mid-brain vesicle is expanded laterally. The hind-brain is a little dilated, as is best seen in dorsal view. The entire outline of the trigeminal crest cannot be distinguished, but its posterior boundary appears as a raised line passing from the dorsal zone of the hind-brain to the upper part of the mandibular arch. The facial-acoustic crest appears as a faintly outlined band lying anterior to the otic pit and merging in the hyoid arch ventrally. The otic pit is a broadly oval depression with prominently raised walls. The glossopharyngeal crest forms a raised band extending from the posterior wall of the otic pit into the third branchial arch. The vagus crest is separated from the glossopharyngeal crest by a broad groove. Its ventral border is indistinct. The first and second gill slits are broken through. The first slit is an elongately oval, the second an almost circular opening. There is a raised oval plate over the third gill pouch. The mandibular arches are seen to be in contact in the oral region. The posterior thirds of these arches are bent so that they lie in the antero-posterior plane of the body. The outline of the heart is barely visible through the walls of the pericardial cavity. Thirty-five or -six pairs of somites are visible externally. The Wolffian duct can be seen as a narrow ridge below the eleventh to sixteenth somites inclusive. A distinct median ridge extends from the middle of the trunk region along the back, around the tail, and for 0.8 mm. along the ventral median line.

Although this embryo measures 0.6 mm. less in length than the preceding one of 5.8 mm., it is considerably farther developed. The chief evidences of this advance are: the more complete separation of the embryo from the blastoderm; the greater flexure of the head, and prominence of the brain vesicles; the breaking through of the two anterior gill slits; the deepening of the otic pit, and the farther development of the median fold. The difference in length is due mainly to the marked tail flexure of the older embryo.

Fig. 21. Embryo 6.2 mm. in length. Normal plate series No. 21. H.E.C. 1637. Lateral view. × 8.

The embryo is turned with the left side toward the blastoderm, to which it is attached by its middle third. The back line is almost straight. The mid-brain, which extends far forward, is bent at right angles to the line of the back and the anterior part of the head is bent downward at an angle of 30° to the mid-brain region. The tail is markedly flexed. The optic vesicle is almost circular, and projects prominently from the side of the head. At the center of the prominence the lentic plate is seen as a faintly outlined circular elevation. Above the optic vesicle is seen a faint arched line — the base of the mid-brain. Behind this, and still above the optic vesicle, is a small rounded swelling caused by the cephalic end of the mandibular somite. The roof of the hind-brain is semi-transparent. The opening of the otocyst is lenticular in outline. Two gill slits open to the pharynx. The third gill cleft is prominent, and the fourth is faintly indicated. The heart tube can be seen through the thin pericardial wall. Forty-four somites can be counted externally. There is a slight tail knob.

The more evident changes shown in this embryo, as compared to the preceding specimen figured, 5.2 mm. in length, are: the absence of the dorsal flexure; the posterior flexure of the fore-brain region; the more complete closure of the otocyst; the appearance of the lentic plate; the increase in number of gill clefts; and the increase in length, and further flexure of the tail.

Figs. 22, 22a, 22b. Embryo 7.5 mm. in length. Normal plate series No. 22. H.E.C. 1503. Lateral, dorsal, and ventral views. × 8.

The yolk stalk has an antero-posterior diameter of 1.5 mm. There is a very slight dorsal flexure above it. The head is bent squarely at right angles to the pharyngeal region. The fore-brain is a little

expanded laterally; the midbrain projects a little from the front of the head. The groove separating fore- and mid-brain is best seen in ventral view (Fig. 22a). The hind-brain is dilated, and its roof is semi-transparent. The olfactory pits appear as a pair of slight depressions lying between the optic cups and the lateral walls of the fore-brain swelling. The optic cup is faintly outlined; it is almost circular and nearly 0.5 mm. in diameter. The edges of the lentic plate are sharply outlined, and there is a distinct central lentic pit. The mandibular somite forms an ill-defined swelling over the optic cup. The trigeminal crest appears as a raised ridge along the posterior border of this swelling. The facial-acoustic crest appears as a faintly outlined plate, anterior to the otocyst. The otocyst is broadly oval in outline and its opening forms a narrow cleft extending backward and upward. The glossopharyngeal crest forms a distinct raised plate immediately behind the otocyst. The vagus crest is distinctly separated from the glosso-pharyngeal. From its dorso-posterior angle a narrow ridge, caused by the dorsal ganglionic commissure, extends backward above the first three somites. Five gill clefts are present — the first two open to the pharynx. The mouth is a narrow cleft 0.5 mm. in length and 0.1 mm. in width. Fifty-nine somites are distinguishable externally. The Wolffian duct extends below the twelfth to thirty-sixth segments inclusive. The median ridge extends backward from the first somite, around the tail, and for 1.2 mm. along the ventral median line.

Figs. 23, 23a, 23b. Embryo 9.0 mm. in length. Normal plate series No. 23. H.E.C. 1495. Lateral, dorsal and ventral views. × 8.

The yolk stalk has an approximate antero-posterior diameter of 2.0 mm. The back line of the embryo is almost straight to within 1.5 mm of the end of the tail. The tail ends in a slightly expanded knob. The primary head bend is a right-angled one. The forebrain is bent at an angle of 45° to the front of the midbrain. The optic vesicles project prominently from the sides of the head. They are broadly oval in outline. There is a distinct central lentic pit. The mandibular and hyoid somites are somewhat collapsed and the boundaries of their dorsal expansions appear as distinct raised ridges. The otocyst causes a prominent oval swelling over the hyoid arch. The swelling immediately behind it is probably caused by both the glossopharyngeal and vagus crests. The first three gill slits are open at their dorsal ends. The fourth and fifth slits are established but do not open to the pharynx. The mouth opening is elongately lenticular in outline; its length is 0.5 mm., its greatest width 0.1 mm. The heart is barely visible through the walls of the pericardium. The ventral wall of the oesophagus, and anterior wall of the vitelline duct, appear as a distinct curved line above and behind the heart. The cloaca forms a very slight swelling on the ventral surface of the body, 1.3 mm. anterior to the tip of the tail. Sixty-three pairs of somites appear externally. The last of the somites is hardly distinguishable in the expanded tail-knob. A median fold extends from the first somite backward along the dorsal median line, around the tail, and forward along the ventral median line to the cloaca.

As compared with the preceding embryo of 7.5 mm., the main changes in this embryo are: the formation of an angle of 45° between the fore-brain and mid-brain; the expansion of the fore-brain; the breaking through to the pharynx of the third gill cleft; the absence of the dorsal flexure; the expansion of the tail knob, and the increase by fourteen of the number of pairs of somites visible externally.

Figs. 24, 24a, 24b. Embryo 11.5 mm. in length. Normal plate series No. 24. H.E.C. 206, 207, 208. Lateral, dorsal, and ventral views. × 5.

These figures are of an embryo of the same length and stage of development as those used in the tables for the internal structure.

The yolk stalk has an anterio-posterior diameter of 1.0 mm. The back line is a little convex. The primary head bend is of 65°, the mesencephalic bend is of 45°. The fore-brain vesicle is expanded laterally and dorsally. In the median line, cranial to the fore-brain swelling, there is a small rounded projection caused by the epiphysis. The mid-brain forms a broad rounded swelling which is a little constricted at its base. A faint groove marks the boundary between mid-brain and hind-brain. The roof of the hind-brain is translucent, — through it can be seen the floor, indented by a deep median groove and five neuromeres. The nasal pits are a pair of grooves placed below and mesial to the eye. They are deeply invaginated at their cranial ends. The optic cup is almost circular. The optic cleft (fissura cupulae, Froriep) is faintly visible. The lens is almost circular in outline. The otocyst is a prominent oval swelling lying over the hyoid cleft. The ductus endolymphaticus can be seen extending upward and backward from its dorsal surface. The premandibular somite appears as a low swelling lying in the angle between the floors of the hind- and fore-brain vesicles. Behind the premandibular somite is seen the fan-shaped expansion of the mandibular somite lying between the roof of the hind-brain and the eye, and extending down into the mandibular arch. Five gill slits are present. The first two are a little expanded at their dorsal ends. Three short gill filaments project from the posterior surface of the hyoid arch. The pharyngeal plate is sharply outlined above and below. The anterior part of the mouth, when seen in direct ventral view, is covered by the projection of the head. The mouth opening is diamond-shaped in outline. The mandibular arches are bent mesially at about their middle, at a angle of 135°. The two arches meet at the base of the mouth at an angle of 75°. The pericardial cavity is dilated and its walls are semitransparent. The pelvic fins appear as rounded ridges, approximately 2.0 mm. in length, lying immediately behind the branchial plate. They extend outward 0.25 mm. from the body. The median ridge is decidedly elevated along the middle of the back and along the ventral median line posterior to the cloaca. In the latter region it is 2.0 mm. high. Seventy-five somites can be counted externally. The anterior somites have the shape of a flattened V, with the apex pointed anteriorly. The dorsal ends of the last twelve somites are directed decidedly anteriorly.

There are many important differences between this and the preceding embryo of 9.0 mm. Among them are: the greater expansion of the fore-brain vesicle; the breaking through of the fourth gill cleft; the distinct boundaries of the branchial plate; the enlargement of the pericardial cavity; the widening of the mouth opening, and bending of the mandibular arches; the appearance of the pectoral fin folds and increased height of the median fin fold; the change in shape of the anterior somites, and increase in number of somites by nearly a fifth.

Fig. 25. Embryo 13.0 mm. in length. Normal plate series No. 25. H.E.C. 223, 224, 226. Lateral view. × 5.

The yolk stalk is almost circular in cross section and nearly 0.1 mm. in diameter. The back line of the embryo is a little convex. The mid-brain projects forward almost as a hemisphere from the front of the head. The fore-brain is expanded ventrally. The caudal border of the head meets the base of the pharyngeal region at right angles. The epiphysis causes a slight median swelling between the fore-brain and mid-brain protuberances. There are five gill slits, the first four of which open to the pharynx. The spiracular cleft is somewhat the longer, and lies at angle of 30° to the longitudinal axis of the body. The pectoral fins are rounded ridges, approximately 1.0 mm. in length, lying above the yolk stalk. The cloaca forms a distinct protuberance from the ventral surface of the body. It is impossible to count the somites. They have the shape of a much flattened ≥ the apices of which point tailwards. A broad shallow groove

extends along the lateral line, from the posterior end of the branchial plate to a point midway between the cloaca and the tip of the tail.

The main external differences between this embryo and the preceding one 11.5 mm. in length are: the greater expansion of the telencephalon and mesencephalon, and the change in shape of the somites.

Figs. 26, 26a, 26b. Embryo 15.0 mm. in length. Normal plate series No. 26. H.E.C. 227, 228, 229. Lateral, dorsal, and ventral views. $\times$ 5.

The head is bent a little ventrally from the hind-brain. The telencephalon is much expanded and extends forward a little over the region of the diencephalon. The epiphysis forms a small median rounded swelling between the telencephalon and mid-brain. The nasal pits are deep semicircular depressions on either side of the telencephalon. The optic cup is 1.0 mm. in diameter. The optic cleft is faintly visible. The roof of the hind-brain is semitransparent. Five gill slits open to the pharynx. The spiracular slit is the longest and lies almost parallel to the longitudinal axis of the body. The posterior borders of the first four branchial arches are prolonged a little backward over the clefts as gill flaps. Three short gill filaments project from each of the second, third and fourth arches. The posterior border of the branchial thickening is sharply defined. The mouth opening is almost as broad as long. The mandibular arches are bent at their middles at an angle of 90°; their bases meet at an angle of 100°. The heart cavity is expanded ventrally, and is a little constricted above. The anterior and posterior dorsal fins are indicated by elevations of the dorsal median fin fold. Each of these elevations is about 1 mm. in length. The pectoral fins lie immediately behind the branchial area or plate and over the yolk stalk. They are 1.0 mm. in length and project 0.5 mm. from the body. The posterior end of each is directed a little ventrally. A broad and shallow groove extends along the lateral line, from the pharyngeal region nearly to the end of the tail. There is a distinct groove between the ventral ends of the somites and the somatopleure below. The cloaca forms a prominent swelling on the ventral surface of the body, 5 mm. from the end of the tail.

The noticeable external differences between this embryo and the preceding one 13.0 mm. in length are as follows: the whole head is bent a little ventrally from the body; the telencephalon and mesencephalon are considerably more expanded; the fifth gill slit is open; gill flaps are developed on the four anterior gill arches; the dorsal fins are differentiated from the dorsal fin fold; the cloaca and the heart chamber are more prominent.

Fig. 27. Embryo 18.0 mm. in length. Normal plate series No. 27. H.E.C. 203, 204, 205. Lateral view. $\times$ 5.

The head, from the posterior boundary of the hind-brain, is bent a little ventrally. The fore-brain is much expanded. The mid-brain is expanded downward as well as in front. The roof of the hind-brain is semitransparent. The optic cup is almost circular in outline; its greatest diameter is 1.4 mm. The walls of the spiracular cleft are in contact. Gill filaments project from the anterior five clefts — those from the hyoid clefts are the longest. The anterior end of the pectoral fin is 0.5 mm. posterior to the branchial plate, and the main body of the fin lies posterior to the yolk stalk. The fin is approximately 2.0 mm. in length at its base. The elevation of the anterior dorsal fin is scarcely noticeable. The posterior dorsal fin is 0.5 mm. in height.

The chief differences between this and the preceding embryo, 15.0 mm. in length, are as follows: the fore-brain is much more expanded and projects farther ventrally; the pelvic and posterior dorsal fins are larger; the gill flaps are farther developed, and the gill filaments are longer.

Figs. 28, 28a, 28b. Embryo 20.6 mm. in length. Normal plate series No. 28. H.E.C. 1494. Lateral, dorsal, and ventral views. × 5.

The fore-brain forms a prominent squarish protuberance from the ventral side of the head. The mid-brain forms an almost hemispherical extension from the front of the head. The angle between the mid- and fore-brain swellings is 130°. The roof of the hind-brain, when viewed from above, is kite-shaped and semitransparent. The nasal pits lie almost in the transverse plane; their anterior and lateral angles are deeply invaginated. The eye is almost circular, 2.0 mm. in diameter. The lens has a diameter of 1.2 mm. and projects as a hemisphere from the optic cup. The ganglion and ramus ophthalmicus superficialis of the facial nerve form a distinct ridge above the eye. The ramus mandibularis of the trigeminal nerve and the ramus hyomandibularis of the facial nerve form together a small ridge extending downward in front ot the spiracular cleft. The spiracular cleft is approximately one half as long as the second gill cleft, and lies at an angle of 45° to the transverse plane of the pharyngeal region. Four short gill filaments project form the spiracular cleft. From the remaining clefts project a large number of gill filaments, the longest of which are 2.5 mm. The gill flaps are prominent: their dorsal ends project backward nearly a millimeter from the side of the body. The mouth opening is oval in outline; its transverse diameter is 1.3 mm., the antero-posterior diameter is 0.8 mm. There is a slight groove separating the bases of the mandibular arches. Both dorsal fins are prominent. The anterior fin is 2.0 mm. long at its base and 0.5 mm. high; the posterior 1.2 mm. long at its base and 0.5 mm. high. The pectoral fin is turned ventrally along its outer border; its base is 2.0 mm. in length. The pelvic fins are low rounded folds which lie on either side of the cloaca and meet behind it. The caudal fin is indicated by the elevation of the dorsal and ventral median fin folds along the posterior 4 mm. of the tail. The somites have the flattened ≷-shape described for the preceding three embryos. The lateral line placode forms a prominent band extending from the last gill slit to a point above the middle of the cloaca. It ends in a knob-like elevation which is due to the separation of the outer layer of the skin in fixing.

This embryo shows a considerable advance in development beyond the preceding one 18.0 mm. in length. The chief differences in the larger embryo are: the depression between the fore- and hind-brain swellings and the projection caused by the epiphysis are obscured by the increase of mesenchyma in this region; the spiracular cleft is shorter, both absolutely and in comparison with the other clefts; the gill filaments are much longer; the elevations of the dorsal fins and of the caudal fin are more definite; the pelvic fin is present; the lateral line placode has become apparent externally.

Fig. 29. Embryo 24.7 mm. in length. Normal plate series No. 29. H.E.C. 1492. Lateral view. × 5.

The fore-brain protuberance is directed a little forward. The mid-brain is almost hemispherical. The roof of the hind-brain is semitransparent. The cerebellum appears as a thickening of the neural tube between the roof of the hind-brain and the mid-brain. The nasal pit no longer appears as a groove invaginated at one end, but as a deep crypt, the edges of which are slightly thickened. The eye is broadly oval in outline. Its vertical diameter (the greater) is 2.5 mm. Long thread-like filaments extend from all the gill clefts; the longest 4.0 mm. in length. The dorsal fins are of about equal size, the anterior one being a little the longer at its base. The caudal fin is of equal height dorsally and ventrally. The outer edge of the pectoral fin is prolonged backward beyond the base of the fin; it ends in a sharp angle posteriorly. The fin rays are faintly visible. The lateral line placode forms a distinct ridge between the epi- and hypo-axial musculature, extending from above the last gill slit to the middle of the caudal fin.

This embryo is similar in general external appearance to the preceding one 20.6 mm. in length. In comparison with the latter, the most noticeable changes are: the change in shape of the nasal pits; the lengthening of the gill filaments; the extension of the pectoral fin; the extension posteriorly of the lateral line placode, and the broadening of the caudal fin.

Figs. 30, 30a, 30b. Embryo 28.0 mm. in length. Normal plate series No. 30. H.E.C. 1357, 233, 221. Lateral view. × 5.

The fore-brain protuberance, when seen in direct ventral view, is almost square; it projects a little anteriorly. The dome-shaped mid-brain swelling projects forward nearly 1 mm. beyond the fore-brain. A shallow external groove marks the boundary between the mid- and hind-brain. The roof of the fourth ventricle is thin but not semitransparent. It is bounded dorsally by two lateral thickenings — the anlagen of the cerebellum. The mouth is approximately three times as broad as long — its upper boundary is obscured by the projection of the fore-brain swelling. The nasal pits are set at only a slight angle to the transverse plane of the head. On the anterior edge of each, the anterior flap of the nasal valve appears as a slightly thickened projection. The posterior flap forms a less well marked projection. The preoral canals appear as a pair of fine lines between the nasal pits, extending forward from the posterior end of the fore-brain swelling. At their anterior ends they separate and arch outward over the mesial edges of the nasal pits. Long gill filaments project from all the gill slits. The spiracular slit is less than a third the length of the remaining ones. The anterior and posterior dorsal fins are each about 0.6 mm. in height. The anterior fin is nearly 2.5 mm. in length at its base, and the posterior fin two-thirds of this length. The dorsal and ventral folds of the caudal fin are of equal height (0.6 mm.) and about 6 mm. in length. The pelvic fins are rounded projections 2 mm. in length and 1 mm. in breadth. The pelvic fins appear as a pair of rounded folds expanded posteriorly. Between their posterior ends is the elevated cloacal plate. The gut forms a prominent rounded ridge, extending forward some distance from the cloacal plate.

The differences between this and the preceding embryo, 24.7 mm. in length, are not extensive. The chief ones are: the increased size of the fore-brain swelling and its projection forward, and the relatively shorter spiracular cleft.

Fig. 31. Embryo 34.0 mm. in length. H.E.C. 363, 176, 353. Lateral view. × 5.

The embryo has the same general shape as the preceding one, but is somewhat broader, both vertically and transversely, in proportion to its length. The mid-brain does not project so prominently, and there is no depression between the mid- and hind-brain swellings. The roof of the hind-brain is not distinctly outlined, as in the preceding specimen. The supra-orbital canal appears as a fine line above the eye. It becomes confluent ventrally with the ethmoid canal, which lies lateral to the nasal pit. The lateral line canal extends nearly to the end of the tail. A row of ampullae lie dorsal to it in the middle trunk region. The posterior and anterior dorsal fins are more rounded than in the preceding specimen and are much thickened at their bases. The posterior edge of each fin extends backward a little from the end of the base. The caudal fin is spatulate in outline. The highest part of the dorsal fold lies a little behind that of the ventral.

Figs. 32, 32a, 32b. Embryo 37.0 mm. in length. N.T.S. No. 32. H.E.C. 363, 176, 353. Lateral, dorsal and ventral views. × 5.

The growth of mesenchymal structures has obscured the outlines of the main divisions of the brain which have, up to this stage, determined the modeling of the head. From the ventral surface of the head,

there extends forward a short broad rostral process. This is separated from the main part of the head above by a shallow groove. The eye is broadly oval in outline, the vertical diameter being equal to about two thirds of the antero-posterior. The edges of the nasal pits are thickened and both anterior and posterior flaps of the nasal valves are prominent. The jaw ridges appear as prominent V-shaped elevations bounding the angles of the mouth. Placed laterally to each ridge is a triangular depression — the labial pocket.

The main divisions of the lateral line system of the embryo can be traced by the rows of ampullae associated with the canals. The supra-orbital canals extend forward from above the gill slits, over and around the front of the orbit; there they become continuous with the ethmoid canals. Each ethmoid canal makes an abrupt median bend in front of the nasal pit and, extending backward, joins the postorbital canal lateral to the angle of the mouth. Although not shown in the figure, in another specimen of the same stage the angular canal arose from this juncture and extended inward around the angle of the mouth, and a short distance along the lower jaw. The preoral canals arise from the ethmoid canals, about midway between the angle of the mouth and the nasal pits; and pass mesially, making an abrupt anterior and a posterior bend. They nearly meet at the median line in front of the mouth. From this point, they extend forward, diverging laterally, and terminate midway between the nasal pits and the anterior end of the rostral process. The postorbital canals extend upward from their juncture with the ethmoids, and end by joining the supra-orbital canals behind the eye. This dorsal termination of the supra-orbital canals is not shown in the figure. Although no occipital canal is shown in the figure, it was present in another embryo of the same stage. There it formed a connection across the median line, between the supra-orbital canals, at the level of the third gill slit. The mandibular group of ampullae appear as a cluster of about twelve pits a short distance behind the angles of the mouth. The posterior infra-orbital ampullae lie in front of the angle of the mouth, and are bounded anteriorly by the preoral, and laterally by the ethmoid canals. The infra-rostral group of ampullae is represented by a few scattered pores lying below the orbit and lateral to the ethmoid canal. The anterior infra-orbital ampullae lie in front of the transverse limb of the preoral canal and posterior to the nasal pit. The hyoid ampullae occupy the upper part of the surface of the hyoid arch, between the spiracle and the upper part of the second gill slit.

The anterior and posterior dorsal fins are thickened and rounded, and a small rounded knob, the spine, projects from the anterior end of the base of each. The caudal fin is spatulate in outline, and its dorsal and ventral folds are of equal height. Both pectoral and pelvic fins project backward some distance from their attachment to the body. The cloacal plate is elongately oval in outline, and is bounded on either side by a rounded ridge. These ridges fuse together in front of the cloaca, but are separated posteriorly by a narrow median cleft.

As compared with the preceding stage, 34.0 mm. in length, the present specimen shows the following changes. The increase of mesenchyma in the head region and the development of the rostral process have obscured the outline of the brain, which has up to this stage determined the modeling of the head; the spines of the anterior and posterior dorsal fins have appeared; the lateral line system is somewhat farther developed.

Tables.

No.	Designation	Size	Preparation Data	Body Form	Somites	Head-Somites
1	H.E.C. 986	Blastoderm 3.0 mm.	Fixative: Aceto-corrosive. Section: Transverse, 6 μ. Stain: Alum cochineal, safranin.	Blastoderm elongately oval in outline, raised a little above the surface of yolk. Segmentation cavity forms a small swelling near posterior end.	—	—
2	H.E.C. 989	Blastoderm 4.2 mm.	Fixative: Aceto-corrosive. Section: Sagittal, 6 μ. Stain: Alum cochineal, safranin.	Blastoderm broadly oval in outline, nearly a half longer than preceding specimen. Posterior margin a little thickened near median line.	—	—
3	H.E.C. 990	Embryo 0.3 mm.	Fixative: Aceto-corrosive. Section: Sagittal, 6 μ. Stain: Alum carmine, safranin.	Blastoderm broadly oval in outline. But little larger than preceding stage. Margin thickened around entire circumference. Embryo a rounded thickening, 0.3 mm. in length antero-posteriorly, on posterior rim of blastoderm. Very shallow rim notch.	—	—
4	H.E.C. 983	Embryo 1.4 mm.	Fixative: Aceto-corrosive. Section: Transverse, 6 μ. Stain: Alum cochineal, safranin.	Embryonic swelling projects forward 1 mm. from thickened posterior rim of blastoderm — a little expanded anteriorly. Shallow rim notch. Well defined median furrow which extends along posterior two-thirds of swelling.	Mesoderm of body a pair of lateral plates continuous with the head mesoderm, narrower anteriorly than posteriorly, distinct from entoderm posteriorly, confluent with it anteriorly.	Head mesoderm represented by a thickening of dorsal wall of archenteron on either side of the notochordal plate.
5	H.E.C. 988	Embryo 1.6 mm.	Fixative: Aceto-corrosive. Section: Sagittal, 6 μ. Stain: Alum cochineal, safranin.	Embryo extends forward 1.2 mm. from posterior rim of blastoderm. Medullary plate 1 mm. in length. Foregut process extends forward 0.2 mm. beyond medullary plate. Shallow rim notch. Deep median furrow in posterior three-fifths of medullary plate.	Apparently one intersegmental cleft.	Like preceding embryo.
6	H E.C. 984	Embryo 1.8 mm.	Fixative: Aceto-corrosive. Section: Transverse, 6 μ. Stain: Alum cochineal, safranin.	Archenteron forms rounded process projecting 0.1 mm. in front of medullary plate. Medullary plate divided into cephalic and chordal portions. Broad shallow rim notch. Median furrow in posterior five-sixths of plate. Caudal swellings differentiated from posterior rim of blastoderm.	Axial mesoderm a pair of lateral ridges projecting from roof of archenteron. No somites. Posteriorly the mesoderm is almost completely separated from the entoderm.	Head mesoderm continuous with archenteron anteriorly, distinct from it posteriorly.
7	H.E.C. 1009	Embryo 2.0 mm.	Fixative: Aceto-corrosive. Section: Sagittal, 6 μ. Stain: Borax carmine, Lyons blue.	Embryo farther raised from blastoderm. Anterior swelling of archenteron hidden by expansion of cephalic plate. Lateral boundaries of archenteron indicated externally by ridges. Deep median furrow extends forward to middle of cephalic plate.	Four pairs of somites — the anterior two well separated. A fifth somite forming anteriorly. Small myocoels in anterior three somites.	Mandibular somite represented by an expansion of the anterior end of head mesoderm. A minute cavity in somite. Entoderm and mesoderm confluent behind this enlargement.
8	H.E.C. 1354	Embryo 2.5 mm.	Fixative: Chromo-acetic. Section: Transverse, 6 μ. Stain: Iron haematoxylin, orange G, and Sudan III.	Tail swelling more definitely marked off laterally from blastodermic rim than in preceding embryo. Lateral boundaries of archenteron appear as distinct ridges on blastoderm, extending from fifth pair of somites to lateral boundaries of tail swellings.	Nine pairs of fully formed somites. The anterior eight possess definite myocoels. Anterior somites slightly constricted ventrally.	A distinct cavity in mandibular somite. Head mesoderm extends a little farther ventrally along sides of archenteron. Preoral mesoderm distinct from entoderm.
9	H.E.C. 997	Embryo 2.7 mm.	Fixative: Aceto-corrosive. Section: Transverse, 6 μ. Stain: Borax carmine, safranin.	Much as preceding embryo (No. 8), except for medullary plate (see brain and cephalic nerves).	Ten pairs of somites, an eleventh in process of formation posteriorly. Anterior somites have a much greater antero-posterior diameter than posterior ones.	Mandibular somite expanded dorsally, connected with the general mesoderm by a broad posterior stalk. Hyoid somite represented by a dorsal enlargement of this stalk. Cells of preoral mesoderm have an epithelial arrangement.
10	H.E.C. 1011	Embryo 3.1 mm.	Fixative: Aceto-corrosive. Section: Transverse, 6 μ. Stain: Borax carmine, safranin.	Anterior half of cephalic part of embryo separated from blastoderm, and bent sharply ventrally.	Twelve pairs of somites (counted from sections). No myocoel in two posterior pairs of somites. Mesial and lateral walls of equal thickness.	Mandibular somite marked off from posterior mesoderm by deep grooves. Lumen enlarged. Preoral mesoderm more distinct from entoderm of foregut than before.
11	H.E.C. 978	Embryo 3.2 mm.	Fixative: Aceto-corrosive. Section: Transverse, 6 μ. Stain: Borax carmine, orange G.	Anterior third of embryo separated from blastoderm. Head turned to right, and a little ventrally. Caudal swellings project abruptly from blastodermic rim, extending backward 0.5 mm. over yolk.	Eleven or twelve pairs of somites (counted from sections).	Much as preceding embryo (No. 10).

Notochord, Subnotochordal Rod, Axial Skeleton	Ectoderm in early Stages	Brain, and Cephalic Nerves	Hypophysis and Infundibulum	No.
—	Upper cells of blastoderm form a fairly definite epithelial layer at the edge of disc, not separated from lower cells centrally. Average length 10 cells 37 μ, breadth 22 μ. Cells loaded with yolk granules.	—	—	1
—	Ectoderm slightly thickened at posterior end of blastodisc. Here generally 2 rows of nuclei, elsewhere 1 row of nuclei.	—	—	2
—	Ectoderm lying over archenteron, much thickened, containing layers of elongate nuclei, long axes of nuclei being directed dorso-ventrally. Cellwalls not distinct. Ectoderm thins out anteriorly. Anterior border of disc made up of one layer of cells, with rounded nuclei. Here there are faint cell walls.	—	—	3
Notochord distinguishable along entire length of archenteron, except extreme anterior and posterior ends, but in no place clearly cut off from it. Anterior fourth of notochord a flat plate, slightly marked off from remainder of archenteron roof by shallow grooves. Posteriorly, plate folded dorsally until almost semicircular in cross section, apex of plate pressing against ectoderm of medullary plate. In trunk region, two rows of nuclei in dorsal part of notochordal plate. Posteriorly, three or more layers of nuclei much more compactly placed than those of archenteron.	Medullary plate approximately 1 mm. long, 0.6 mm. broad, rounded semicircularly anteriorly. Median groove along posterior two thirds. Groove shallow and rounded anteriorly, becoming deeper and more angular posteriorly. Epithelim contains 5 rows of nuclei at sides of plate, and 2—3 rows of nuclei in groove. Clear outer zone of cytoplasm in cells forming floor and sides of groove.	—	—	4
Notochord still attached to archenteron throughout.	Medullary plate broadly expanded anteriorly, approximately 1 mm. broad and 1 mm. long. A deep median groove in posterior three fourths of plate, anterior fourth almost flat. Epithelium 60 μ thick at lateral edge of plate.	—	—	5
Notochordal plate extends from posterior edge of head expansion backward to middle of embryo, occupying median third of dorsal roof of archenteron, curved slightly downward, nuclei gathered at dorsal surface. In the middle of trunk region notochord distinctly separated laterally from entoderm but still forming part of archenteron roof. Here flatly oval in cross section, ventral ends of notochordal cells directed mesially. Posterior to this region notochordal plate again fused laterally with entoderm, and a distinct notochordal groove present. Notochord distinct posteriorly to within 60 μ of incisura neurenterica.	Medullary plate more slender and longer than in preceding stage (No. 5). Elongately oval in outline, 0.7 mm. wide, 1.1 mm. long. Lateral edges extend a little outward over body of embryo. Rounded median groove along posterior four fifths, anterior fifth almost flat. For subsequent history of ectoderm see tables on brain, chord and integument.	—	—	6
Much like preceding stage (No. 6).	—	Medullary plate widely expanded anteriorly to form cephalic plate. Cephalic plate broadly oval in outline, 1 mm. long and a little over 5 mm. broad. Edges of plate turned a little ventrally. A shallow median groove along posterior three fifths of the cephalic plate.	—	7
Notochord completely cut off from archenteron, except extreme posterior and anterior ends. Roundly oval in cross section in head and pharynx region. Round in cross section in trunk region. Diameter in trunk region 50 μ. A distinct elastica externa for greater part of length. Nuclei of middle third of notochord, when seen in cross section, are arranged as a ring with cytoplasmic core and border. — Subnotochordal rod indicated by an occasional cell on dorsal surface of archenteron, just below notochord.	—	Cephalic plate broadest in front, narrowing posteriorly. Sharply marked off from cordal folds posteriorly. Approximately 1 mm. long, 0.7 mm. broad, shallowly concave. Anterior end deeply indented on either side of the median line by developing optic vesicles. Three neuromeres of LOCY on left side, four on right.	—	8
Notochord separate from archenteron except for extreme anterior and posterior ends. Anteriorly it bends ventrally and is lost in cells of preoral mesoderm. Greatest diameter 45 μ. — Subnotochordal rod forming as a ridge on dorsal surface of archenteron in middle trunk region. Ridge one cell thick only, nuclei turned with their long axes at right angles to longitudinal axes of cells.	—	Cephalic plate less definitely marked off from myelon plate posteriorly, approximately 1 mm. broad and long. Optic vesicles form a deep semicircular depression in anterior part of plate, ending abruptly posteriorly, slightly evaginated laterally. Medullary groove broad and shallow, extends forward to optic vesicle. Posterior to optic vesicles, lateral edges of medullary plate are turned ventrally.	—	9
Anterior end of notochord as in preceding stage (No. 9). Greatest diameter of notochord, in pharyngeal region, 60 μ. In tail region, notochord wedge-shaped in cross section, the ventral edge projecting downward toward archenteron cavity but separated from it by a thin band of entodermic cytoplasm. Nuclei in mid-trunk region have ring-like arrangement described for No. 8. Entoderm, notochord, and mesoderm fused 25 μ anterior to incisura neurenterica. — Subnotochordal rod as described for No. 9.	—	No definite line of distinction between posterior end of cephalic plate and myelon plate, although indicated at the lateral edges by a shallow notch. Optic vesicles much expanded laterally, extend backward as blind pouches for three sections of 6 μ. Lateral edges of cephalic plate bent ventrally.	—	10
Notochord as in preceding embryo (No. 10). — Subnotochordal rod much as before, forming a low broad ridge in the 6th, 7th and 8th segments.	—	A slight primary head bend. Medullary folds of brain region very high, their edges only turned a little outward. In posterior brain region medullary groove deeply V-shaped.	—	11

No.	Spinal Chord, Spinal Nerves, Sympathetic	Eye	Nose	Ear	Integument, Lateral Line	Mouth
1	—	—	—	—	—	—
2	—	—	—	—	—	—
3	—	—	—	—	—	—
4	—	—	—	—	—	—
5	—	—	—	—	—	—
6	—	—	—	—	Transition from skin-epithelium to neur-epithelium very gradual. Ectoderm at base of medullary plate 40 μ thick, showing two layers of nuclei in cross section. Ectoderm over blastodisc thickly squamous.	—
7	Chordal portion of medullary plate (myelon plate), .75 mm. long, .25 mm. wide. Indented by a well defined median groove.	—	—	—	Ectoderm of blastodisc a little thicker than in preceding stage (No. 6).	—
8	Medullary canal deeply V- or U-shaped in cross section. Edges of medullary folds turned a little ventrally just posterior to cephalic plate.	Optic vesicles a pair of very shallow depressions in anterior half of cephalic plate, separated at median line by a low ridge.	—	—	Sharp transition between neur- and skin-ectoderm in the tail and trunk region. In the pharyngeal and cephalic regions distinction less marked. Ectoderm of tail and trunk region thickly squamous, with large closely packed nuclei. In cephalic region epithelium 35 μ to 55 μ thick, with two rows of nuclei in cross section: ventrally, where it is somewhat thinner, one row of nuclei present. On lateral surface of pharyngeal region epithelium 35 μ thick, slightly thinner above.	—
9	Medullary canal broadly V-shaped in cross section anteriorly.	Optic vesicles form a single deep semicircular depression in anterior part of cephalic plate. A little evaginated laterally, ending abruptly posteriorly.	—	—	Much the same as in preceding stage (No. 8).	—
10	Like preceding stage (No. 9).	Optic vesicles expanded laterally, and extending backward from posterior wall of fore-brain for three sections of 6 μ.	—	—	Much as preceding stage (No. 9). Cells of cephalic epithelium have a clear inner zone. Epithelium ventral to pharynx low cuboidal.	—
11	Medullary folds in contact anteriorly for 52 sections of 6 μ.	Ventral part of optic vesicles expanded laterally.	—	—	As preceding stage (No. 10).	—

Archenteron	Pharynx, Thyreoid, Thymus, Suprapericardial Body	Digestive Tube	Liver, Pancreas, Spleen	Urogenital System	Heart, Pericardium, Blood Vessels	Extremities	Remarks	No.
No invagination.	—	—	—	—	—	—	—	1
Invagination of archenteron forms a very shallow bay in posterior edge of blastoderm. Epithelium of the roof contains four of five rows of nuclei. No definite anterior end of archenteron, the entodermal cells there pass gradually off into the indifferent cells of the blastoderm.	—	—	—	—	—	—	—	2
Archenteron a broad shallow invagination about 0.75 mm. in width, extending anteriorly from the posterior border of the blastodisc for approximately one tenth its length (i. e. 0.2 mm.). Epithelium of roof contains 3—5 rows of nuclei.	—	—	—	—	—	—	—	3
Archenteron 0.75 mm. in length (by sections). A few cells from anterior end and from anterior part of lateral walls extend ventrally to form floor of archenteron in that region.	—	—	—	—	—	—	—	4
Archenteron 0.7 mm. in length. A slight fold in anterior wall indicates beginning of formation of preoral process. Cells in floor of archenteron have increased in number. The nuclei of the anterior part of the roof lie at base of cells, leaving a clear outer border.	—	—	—	—	—	—	—	5
Preoral gut projects forward as a distinct pouch for 6 sections of 6 μ. Posterior to preoral archenteron almost square in cross section. Extreme anterior part of fore gut floored by entoderm. Posterior to this, entodermal cells form narrow shelves on lateral edges of floor.	—	—	—	—	—	—	Reconstructed. Fig. 1. General structure.	6
Preoral gut 92 μ in length, ending bluntly anteriorly. Archenteron floored by entodermal cells for 120 μ posterior to preoral gut. Small pocket in floor of archenteron just behind foregut.	—	—	—	—	—	—	Reconstructed. Fig. 2. General structure.	7
Preoral gut 240 μ in length (by sections), pointed anteriorly, broadly oval in cross section posteriorly. Anterior third of archenteron floored with entoderm. Lateral floor shelves of entoderm extend along greater part of length of archenteron.	—	—	—	—	—	—	—	8
Preoral gut widely expanded laterally. Posterior to foregut, archenteron triangular in cross section. Entodermal cells form floor of anterior third of archenteron, broad lateral floor shelves posteriorly.	—	—	—	—	—	—	Reconstructed. Figs. 3 and 4. General structure.	9
Preoral gut extends through 45 sections of 6 μ. For further history of archenteron see tables on pharynx and digestive tube.	—	—	—	—	—	—	—	10
—	—	—	—	—	—	—	—	11

No.	Designation	Size	Preparation Data	Body Form	Somites	Head-Somites
12	H.E.C. 994	Embryo 3.2 mm.	Fixative: Aceto-corrosive. Section: Sagittal, 6 μ. Stain: Borax carmine, orange G.	Anterior sixth of embryo separated from blastoderm, and turned a little to the right. Caudal swellings as in preceding stage (No. 11).	Thirteen pairs of somites (counted from sections), fourteenth forming posteriorly.	Mandibular somite separated from posterior mesoderm dorsally, broadly connected ventrally. A small lumen in hyoid somite.
13	H.E.C. 980	Embryo 3.3 mm.	Fixative: Aceto-corrosive. Section: Transverse, 6 μ. Stain: Borax carmine, orange G.	Head and a little of anterior part of trunk of embryo separated from blastoderm, and turned to the right. Caudal swellings longer and narrower than in preceding embryos (Nos. 11 and 12).	Fifteen pairs of somites (counted from sections). Vertical diameter of anterior somites greater than in preceding stage. Mesial walls of anterior two or three pairs of somites thicker than lateral.	Mandibular somite completely cut off dorsally from the posterior mesoderm, much dilated anteriorly, compressed posteriorly. Hyoid somite broadly connected with the posterior mesoderm.
14	H.E.C. 982	Embryo 3.5 mm.	Fixative: Aceto-corrosive. Section: Transverse, 6 μ. Stain: Borax carmine, safranin.	Head and a little of trunk of embryo separated from blastoderm. Head bent ventrally.	Sixteen pairs of somites, seventeenth forming posteriorly. Last inter-somatic cleft lies approximately 200 μ anterior to incisura neurenterica.	Mandibular somite consists of a greatly dilated anterior portion and a flattened ventral process which is attached to the general mesoderm by a narow stalk. Hyoid somite somewhat dilated, but still connected posteriorly and ventrally with the general mesoderm.
15	H.E.C. 1499	Embryo 3.25 mm.	Fixative: Aceto-corrosive. Section: Transverse, 6 μ. Stain: Iron haematoxylin, Congo red.	Head and pharyngeal region separated from blastoderm. Head bent ventrally at right angles to pharyngeal region. Incisura neurenterica sharply marked.	Fifteen pairs of somites. A very slight outpouching of lower half of mesial wall of somites in anterior trunk region to form sclerotome. Dorsal to this outpouching, mesial wall thickened, obliterating upper part of myocoel.	Mandibular somite connected with hyoid somite by a few cellular strands.
16	H.E.C. 930	Embryo 4.0 mm.	Fixative: Aceto-corrosive. Section: Transverse, 6 μ. Stain: Borax carmine, Lyons blue.	Anterior fourth and posterior eighth of embryo separated from blastoderm. Head bent ventrally at a little more than right angles to pharyngeal region. Incisura neurenterica completely enclosed.	Nineteen pairs of somites (counted from sections). In cardiac region, sclerotomic bud expanded mesially until in contact with notochord. Distinct line of differentiation between dorsal boundary of sclerotomic bund and myotome.	Anterior end of mandibular somite much expanded. Vertical diameter of stalk connecting it with general mesoderm is one third that of somite. Small cavity in hyoid somite. Hyoid somite separated from mandibular by narrow cleft. Connected with general mesoderm by two bands of mesoderm, one passing down second gill arch and one over second gill pouch.
17	H.E.C. 1498	Embryo 3.8 mm.	Fixative: Aceto-corrosive. Section: Transverse, 8 μ. Stain: Iron haematoxylin, Congo red.	Anterior two-fifths and posterior one-fifth of embryo separated from blastoderm. Pharyngeal region bent a little ventrally from trunk. Head bent ventrally at an angle of 60° to pharyngeal region.	Twenty-five or twenty-six pairs of somites (by sections). Segmented mesoderm extends to cloaca. No myocoel in posterior six pairs of somites. In posterior oesophageal and cardiac regions, somites possess definite solid sclerotomes, which may extend dorsally nearly to dorsal surface of notochord. Myocoel obliterated in dorsal half of these somites. In anterior yolk stalk region, sclerotomes represented by outpoutchings of the lower half of the mesial wall of somites. In posterioryolk stalk and trunk regions, no trace of formation of sclerotome, — mesial and lateral walls of somites of equal thickness.	Mesial walls of mandibular somites much thickened, slightly mesenchymal. A cellular bridge connects the two somites just in front of notochord. Hyoid somite connected with the mandibular somite for one section (6 μ) on the left and two sections on the right side. Anterior somite a distinct solid process extending dorsally and laterally from preoral mesoderm.
18	H.E.C. 1398	Embryo 4.8 mm.	Fixative: Aceto-corrosive. Section: Transverse, 10 μ. Stain: Iron haematoxylin, safranin.	Embryo connected with blastoderm by a little more than its middle third. Tail and pharyngeal regions bent a little ventrally from trunk. Head bent ventrally at an angle of 60° to pharyngeal region.	Twenty-six or twenty-seven pairs of somites (counted from sections). Anterior somites well differentiated in sclerotome, myotome. and dermatome. Anterior to middle of trunk, sclerotome differentiated and myotome thicker than dermatome. Cells of myotomes of anterior ten somites elongated until nearly filling myocoel. Sclerotomes becoming slightly mesenchymous. In five anterior somites, sclerotome extends upward to dorsal surface of notochord.	Mesial part of premandibular somite attached to floor of preoral gut. A small cavity in each lateral enlargement of the somite. Lateral walls of enlargements epithelial. Three irregular cavities in median stalk, just below end of notochord. Stalk of mandibular cavity elongated as compared with preceding embryo (No. 16), its vertical diameter approximately one-fourth that of expanded anterior portion.
19	H.E.C. 1497	Embryo 5.8 mm.	Fixative: Chromo-acetic. Section: Transverse, 6 μ. Stain: Iron haematoxylin, Congo red.	Embryo attached to blastoderm for two-fifths of its length. A decided dorsal flexure over attachment. Head bent nearly at right angles to dorsal line of pharynx. Tail bent a little ventrally to trunk. Slight enlargement of tail knob.	Thirty-three somites (counted from sections). Segmented mesoderm extends as far as posterior boundary of cloaca. In cardiac and in anterior half of yolk stalk region, sclerotomes mesenchymous.	—

Notochord, Subnotochordal Rod, Axial Skeleton	Ectoderm in early Stages	Brain, and Cephalic Nerves	Hypophysis and Infundibulnm	Spinal Cord, Spinal Nerves, Sympathetic	No.
Anterior end of notochord as in preceding stages (Nos. 9, 10 and 11). Greatest diameter, in anterior trunk region, 60 μ.	—	Medullary folds of cephalic region bent strongly mesially. They have met and fused for 30 μ at anterior tip of head.	—	Differs but little from preceding embryo (No. 11).	12
Anterior tip of notochord bent sharply downward. In pharyngeal and anterior trunk region, broadly oval, transverse diameter being the greater. In tail region, the greater diameter is vertical. Nuclei arranged in ring form from level of the first pharyngeal pouch to ninth segment. — Subnotochordal rod a flattened ridge on roof of archenteron in the middle trunk region.	—	Medullary folds fused at anterior (ventral) end of fore-brain. They almost meet over mid-brain. Mid-brain vesicle expanded a little laterally. In hind-brain region, edges of medullary folds turned laterally. Medullary canal widest ventrally in hind-brain region. — A very slight proliferation of cells for 130 μ at the skin and neur-ectoderm junction in hind-brain region. Proliferation shows two to four cells in cross section. Hind-brain still open in this region.	—	Medullary canal closed for 120 μ (by sections) in middle trunk region. Anterior to closed region folds are almost in contact. Posterior to closed region canal deeply U-shaped in cross section. Folds are beginning to extend dorsally over incisura neurenterica.	13
Anterior tip of notochord turned ventrally at an angle of approximately 130°. Shape as described in preceding embryo. Greatest diameter in trunk region 60 μ; in head region 40 μ. — Subnotochordal rod as described for preceding embryo (No. 13).	—	Medullary folds almost in contact throughout brain region — fused over mid-brain and at the anterior (ventral) end of fore-brain. Deep recessus post-opticus. Mid-brain a little expanded laterally. Medullary canal in hind-brain region widest ventrally. — Distinct neural crest extending for 300 μ (by sections) along hind- and mid-brain. Crest extends downward over dorsal fourth of neural tube. Ventral border irregular. A slight division into middle and hind cephalic crest (?).	—	Medullary folds in contact along most of the length of canal, fused over anterior two-thirds of it. Incisura neurenterica widely open.	14
Notochord almost round in cross section; of the same diameter as in preceding stage (No. 14). — Subnotochordal rod much as in preceding stages (Nos. 12 and 13). Ridge best marked at level of seventh segment.	—	Anterior (ventral) part of fore-brain region closed, but skin and neur-ectoderm still in contact. Medullary folds almost meet throughout remainder of brain region, except over anterior end of hind-brain where they are turned a little outward. Mid-brain vesicle dilatated laterally. In hind-brain region, floor and sides of medullary groove of equal thickness. — Neural crest extends from a little behind closed portion of neuropore to middle part of hind-brain, showing generally five to eight cells in cross section.	—	Cordal portion of medullary canal closed, except for 150 μ (by sections) posteriorly; here there is still a narrow dorsal cleft. Incisura neurenterica still open, but very deep, its folds approaching dorsally. Cord broadly oval in cross section; in anterior part vertical diameter greater posteriorly, transverse diameter greater. Lateral walls a little thicker than roof or floor.	15
Anterior end of notochord turned ventrally at an angle of nearly 90°. Tip almost separated from preoral mesoderm. In head region, notochord 40 μ in diameter; in trunk region 70 μ in diameter. Nuclei are arranged in ring throughout trunk region. — Subnotochord rod extends from first pharyngeal pouch nearly to tail. Posterior to the second pharyngeal pouch it forms a ridge 15 to 20 μ in height. Detached from roof of archenteron for a few sections in anterior trunk region.	—	Fore-, mid- and hind-brain vesicles separated by shallow grooves on external surface. Small anterior neuropore; skin and neur-ectoderm fused at median line anterior and posterior to it. Deep recessus postopticus. Roof of anterior end of hind brain composed of a single layer of columnar cells. Ventral and dorsal thirds of canal in hind-brain expanded laterally. — Cephalic crest divided into an anterior trigeminal-facial portion and a posterior glossopharyngeal-vagus portion. Trigeminal-facial crest extends forward nearly to anterior neuropore. A smal process from the crest, posterior to optic vesicle, represents thalamic nerve? Two small interruptions in posterior part of trigeminal-facial crest indicate line of division between trigeminal and facial portions. Glossopharyngeal-vagus crest triangular in shape. No division into separate nerve anlagen.	—	Diameter of cord in anterior trunk region twice that in tail region. Vertical diameter greater in anterior trunk region, transverse diameter greater posteriorly. Neurenteric canal completely enclosed.	16
Anterior end of notochord slightly recurved. In anterior trunk region, nuclei form a dense central cluster. In posterior trunk region, nuclei arranged in central ring. In region of cloaca and backward, notochord again cellular. Diameter of notochord in trunk region 90 μ. — Subnotochordal rod detached from gut in trunk region.	—	Anterior neuropore completely closed. Skin- and neur-ectoderm fused at median line, in region of neuropore, for 150 μ (by sections). Roof of hind-brain, anterior to otic plate, thin and expanded: at median line composed of a single layer of cells. — Trigeminal crest a broad sheet of cells, attached to roof of anterior end of hind-brain by a broad dorsal process, urtrochlearis. Posteriorly, attached to dorsal third of hind-brain. Extends ventrally nearly to base of mandibular arch. Thalamic-ophthalmic process from roof of mid-brain to anterior border of crest. Facial acoustic crest extends ventrally to level of aorta. Glossopharyngeal and vagus crests separated; former extending over dorsal half of neural tube, latter indicated by a few cells only in 6 sections of 6 μ.	—	Much like preceding stage (No. 16).	17
Anterior end of notochord bent ventrally, not recurved. Extreme ventral end attached to dorsal surface of premandibular somite. Diameter of notochord in largest part (anterior trunk region) 90 μ. Nuclei gathered in central cluster from second gill pouch backward to eighteenth segment, arranged in ring form from this point backward to cloaca. — Subnotochordal rod appears as median ridge on roof of pharynx at level of anterior edge of facial nerve, completely separated from gut from heart region backward nearly to cloaca. Three distinct ventral processes along free portion of rod.	—	Cranio-caudal axis of fore-brain much increased as compared with preceding stage. Anterior neuropore completely closed. Skin and neur-ectoderm fused in median line for a distance of 80 μ (by sections) at this point. Roof of hind-brain, anterior to otocyst, expanded; at median line composed of a single layer of cells. Ventricle greatly expanded dorsally; reduced in middle third, by thickening of lateral walls, to a narrow slit; a little enlarged ventrally. In otic region, brain almost oblong in cross section; transverse diameter half of vertical. Dorsal and ventral expansions of canal of equal size. — Thalamic crest and ophthalmic portion of trigeminal crest form a broad cellular band, lying dorsal to optic vesicle. Trigeminal and urtrochlear crests broadly connected. Acoustic portion of facial acoustic crest attached to epithelium of otic pit. Facial portion enlarged at level of dorsal aorta, extends down dorsal third of hyoid arch. Glossopharyngeal crest extends nearly to base of hind-brain. Vagus crest completely separated from glossopharyngeal, 250 μ in length (by sections). Extends anteriorly over dorsal two-thirds of medullary tube, gradually becoming narrower posteriorly.	—	Vertical diameter of cord greatest throughout. Lumen elongately oval in anterior trunk region, becoming almost circular posteriorly, larger dorsally than ventrally throughout greater part of trunk region. Lateral walls thicker than roof or floor throughout.	18
Anterior end of notochord fused with median portion of premandibular cavity. Nuclei approximately as in preceding stage (No. 18). — Subnotochordal rod attached to dorsal wall of pharynx from above first gill slit to middle of oesophagus. In some sections cells arranged as about a lumen.	—	Skin- and neur-ectoderm fused for 48 μ (by sections) along median line in position of neuropore. Transverse diameter of anterior end of hind-brain greater than vertical. Ventral expansion of ventricle from otocyst backward. — Thalamic and urtrochlear crests attached to trigeminal by narrow strands of cells. Vagus crest separated from glossopharyngeal: extends ventrally below dorsal wall of oesophagus.	—	In cardiac and anterior trunk region, transverse diameter of cord two-thirds of vertical. Lateral walls almost in contact. In posterior trunk region, cord ovate in cross section — broadest dorsally; transverse diameter almost equal to vertical; ventral half of canal reduced to a narrow slit. In tail region, cord almost circular. Canal almost circular, and dilated anterior to neurenteric canal. Neural crest extends posteriorly to thirteenth segment.	19

No.	Eye	Nose	Ear	Integument, Lateral Line	Mouth	Arch-enteron	Pharynx, Thyreoid, Thymus, Suprapericardial Body
12	As preceding stage (No. 11).	—	—	As preceding stages (Nos. 10 and 11).	—	—	Position of first gill pouch indicated by a slight lateral enlargement of pharynx.
13	As preceding stages (Nos. 11 and 12).	—	—	Epithelium in tail and trunk region 10 μ thick, nuclei spherical and closely packed. In anterior pharyngeal region the lateral thickening, described for No. 8, extends from a little below roof of gut to dorso-median line above, 35 μ thick, two rows of nuclei.	—	—	First gill pouch distinct.
14	Optic vesicles extend posteriorly 40 μ (by sections) from fore-brain. Expanded laterally, dorsal walls extending outward nearly at right angles to walls of fore-brain.	—	Ectoderm a little thickened on either side of medullary tube just posterior to first gill pouch. 15 μ in thickest part.	As in preceding stage (No. 13), except that lateral thickening is more definitely outlined. The dorsal and anterior portion of thickening becoming differentiated into otic plate. (See ear.)	—	—	Fore gut approximately 0.3 mm. in length. First gill pouch distinct.
15	Like preceding stage (No. 14).	—	Thickening of otic placode lies over second gill pouch. A little more differentiated from skin ectoderm than in preceding stage. Greatest thickness 35 μ.	Like preceding stage (No. 14). (See nose and ear for special thickenings.)	—	—	Pharynx 325 μ in length (by sections). Preoral gut extends 30 μ anterior to pharynx proper, opens into pharynx floor 20 μ behind anterior wall. First gill pouch well established. Second gill pouch a shallow groove, present on right side only.
16	Optic vesicles broadly expanded anteriorly and dorsally.	—	Unchanged from preceding stage (No. 15).	Skin-ectoderm not over 18 μ thick in cephalic region except around neuropore and where sense organs are developing. Ectoderm is somewhat thickened on either side of pharynx. This thickening extends posteriorly as far as anterior part of yolk stalk. For epithelium of median ridge, see extremities.	Epithelium thickened to form oral plate. In contact with floor of pharynx posteriorly.	—	Pharynx slightly larger anteriorly than posteriorly. Two gill pouches; first pouch in contact with ectoderm for over half its length; second pouch in contact with ectoderm for short distance in its middle part.
17	Optic vesicles extend forward 32 μ (by sections) from attachment to fore-brain. Anterior half of dorsal wall slightly overlaps fore-brain.	—	Anterior part of otic placode very slightly depressed. 45 μ in thickness in thickest part. Sharply differentiated from skin-ectoderm dorsally, other borders not sharply marked off. Resting nuclei lie in inner part of epithelium, leaving a broad clear outer zone in which are many mitoses. Cells of auditory crest fused with ventral part of placode.	Ectoderm in pharyngeal region forms a fairly definite plate 15—30 μ thick. Cells in this region distinct, columnar, with elongate nuclei. In posterior part of trunk, where still continuous with the blastodisc, epithelium extremely flattened, with elongate flattened nuclei.	As preceding stage (No. 16).	—	Ectoderm and entoderm in contact over greater part of first pouch; fused at cephalic end. Cleft of first slit distinctly marked externally. Ectoderm and entoderm in contact over second pouch, but not fused. Thyreoid a shallow ventral groove in floor of posterior part of pharynx.
18	Optic vesicles decidedly expanded anteriorly and dorsally. Optic stalk narrower than vesicle — posterior wall of stalk projects at right angles from fore-brain.	Nasal placodes a pair of distinct thickenings of epithelium lying on either side of the closed ventral (anterior) end of neuropore, and ventral to the optic vesicles.	A distinct though shallow depression in anterior and dorsal part of otic placode. Epithelium of placode thickest dorsally. Greatest thickness 80—85 μ.	The portion of lateral placode not involved in formation of otic plate, has become indistinguishable from surrounding epithelium. Otherwise, integument as in preceding stage (No. 17).	Oral plate slightly depressed. Ectoderm and entoderm fused.	—	Pharynx expanded anteriorly; ectoderm and entoderm fused over first gill pouch for one half its length. Entoderm of second pouch in contact with ectoderm for a short distance. Thyreoid a distinct pouch from floor of pharynx.
19	Ectoderm slightly thickened, forming a lentic plate over optic vesicles. Optic vesicles much expanded dorsally and cranially. Lateral surface of vesicles flatly concave. Optic stalks one-third as long, and one-half as wide as vesicles.	Like preceding stage (No. 18).	Deep otic pit in anterior part of placode. Anterior wall of pit turned inward at right angles to skin-ectoderm. Edge of anterior part of dorsal wall slightly overhanging. Ventral and posterior edges pass gradually over into skin-ectoderm.	Epithelium over hind-brain very much flattened. Epithelium of cephalic region about same thickness as that over body.	As preceding stage (No. 18).	—	First two gill pouches well defined, third pouch indicated dorsally. Ectoderm and entoderm over first two fused; in contact over third pouch. Walls of thyreoid sac in contact.

Digestive Tube	Liver, Pancreas, Spleen	Urogenital System	Heart, Pericardium, Blood Vessels	Extremities	Remarks	No.
—	—	—	—	—	—	12
Gut anteriorly triangular in cross section, twice as high as broad; walls much thickened dorsally (45 µ). Posteriorly, gut rapidly flattens as it approaches rim of blastodisc. Walls of equal thickness (30 µ), dorsally and ventrally.	—	—	—	—	—	13
Gut anteriorly broadly triangular in cross section; posteriorly, walls spread out until almost flat.	—	—	—	—	Reconstructed Figs. 5 and 6. General structure.	14
Anteriorly, gut higher and narrower than in preceding stage. Floored with entoderm anteriorly for 200 µ (by sections).	—	—	—	—	—	15
Oesophagus approximately 0.1 mm. in length (by sections). Nearly three times as high as broad. Antero-posterior diameter of yolk stalk 2 mm. Hind gut 0.25 mm. in length. Twice as high as broad; expanded dorsally.	—	—	Endothelial tube of heart indicated by two strands of cells lying on either side of ventral part of pharynx. In some sections vascular cells arranged as about a lumen. Ventral ends of lateral plates of mesoderm turned mesially, and enclose in part the vascular cells of this region. — Irregular, often interrupted, cords of vascular cells represent first aortic arch and aortae in pharyngeal region. A few cells on either side of subnotal rod in middle trunk region represent a second segment of aortae. Anlage of ventral aorta not connected with that of first aortic arch? Vitelline veins small, irregular, often collapsed. Can be traced backward only a few sections from heart. Left vitelline vein larger and more distinct than right.	Ectoderm forms a narrow thickened plate along the median dorsal line of the trunk and tail. In middle trunk region it is elevated, forming a median fold 23 µ high. No mesenchyma between dorsal surface of neural tube and ectoderm.	Reconstructed Fig. 7. General structure. Fig. 17. Head somites.	16
Oesophagus two thirds as broad as high. Lateral walls 60 µ in thickness. Antero-posterior diameter of yolk stalk 2 mm. Hind gut 0.3 mm. in length; lateral walls and roof muck thicker than floor.	—	Three solid pronephric anlagen projecting from 7th, 8th and 9th segments. Wolffian duct a solid cord of cells attached to first, second, and anterior part of third pronephritic anlagen; does not extend posterior to 9th segment.	Anterior part of primitive coelom somewhat dilated to form pericardial cavity. Endothelial tube of heart bifurcated behind, simple straight tube anteriorly. Mesothelial layer of heart connected with splanchnic mesoderm above by a broad dorsal mesocardium, below by a narrow ventral mesocardium which is interrupted for three or four sections in middle heart region. — Ventral aortae, first aortic arch, dorsal aortae, and anterior ends of vitelline veins represented by cords of vascular cells, which are generally continuous and in some places arranged as though about a lumen. Cells of dorsal aortae extend posteriorly to middle of trunk.	Median fold extends over a greather length of trunk region than in preceding embryo. Greatest height 30 µ. Median thickening extends to end of tail. Ectoderm thickened along median ventral line of tail.	—	17
Oesophagus very much flattened laterally; in narrowest portion twice as high as broad; lateral walls almost in contact. Gut expanded laterally just in front of cloacal region. Ectoderm and entoderm in contact for 30 µ (by sections) on ventral surface of cloaca. Neurenteric canal widely open.	—	Pronephric anlagen solid, present on 7th, 8th and 9th segments, and just forming on 10th segment on left side. Wolffian duct solid, sickle-shaped in cross section anteriorly, circular posteriorly; extends through 26 sections of 6 µ. Fused with ectoderm for last two or three sections.	Heart 0.25 mm. in length (by sections). Ventral mesocardium entirely broken down. Dorsal mesocardium continuous length of heart, but very thin over middle of heart tube. Posteriorly, heart distinctly dilated on the right side. Endothelial tube bifurcated in posterior part of heart. — Ventral aortae and first aortic arch thin-walled tubes. Dorsal aortae extremely irregular in calibre, apparently solid in places, extend along the anterior two thirds of trunk. Fused to form a single vessel over anterior part of yolk stalk. A small enlargement and division of dorsal aorta on left side, over second gill pouch, represents beginning of second aortic arch? — Vena capitis medialis represented by a small median vessel from anterior end of aorta. Right and left vitelline veins can be traced from heart to blastoderm. Left vitelline vein the larger. Scattered vascular cells, representing subintestinal veins, extend backward on either side of gut nearly to cloaca. Continuous with vitelline veins anteriorly?	Median fold extends around tail and for 120 µ (by sections) along ventral line.	Reconstructed. Fig. 8. General structure. Fig. 18. Head somites.	18
Oesophagus approximately twice as high as broad. Antero-posterior diameter of vitelline duct 130 µ (by sections). Intestine approximately 0.5 mm. in length (by sections) from posterior wall of vitelline duct to the cloaca. A broad shallow groove on right side of upper part of intestine, may represent beginning of spiral valve. Lumen of intestine constricted dorsally. Vertical diameter of cloaca two and one half times transverse. Ectoderm and entoderm in contact on ventral surface. Neurenteric canal widely open.	Liver a shallow pouch, 56 µ in length (by sections) in ventral wall of gut, where joining yolk stalk. Shallow lateral grooves on external surface of gut mark dorsal boundaries of liver pouch.	Solid pronephric anlagen from 7th to 11th segments inclusive. Wolffian duct solid, but cells of anterior end are arranged as though about a lumen. Extends posteriorly for 47 sections of 8 µ.	Heart somewhat expanded as compared with preceding stage (No. 18). Middle half of dorsal mesocardium broken through. Posterior fourth of endothelial tube of heart bifurcated. — Dorsal aorta extends backward nearly to cloaca. Bifurcated at its extreme posterior end and from the middle of the oesophagus to above first gill pouch. Three diverticula of aorta on right side represent pronephric arteries. First and second aortic arches completely formed. Ventral aortae separate throughout. — Vena capitis medialis broadly connected with anterior end of aorta. Extends forward from this connection to optic cup, and backward to posterior edge of trigeminal crest. Right and left vitelline veins extend to blastoderm. Left vitelline vein the larger. Right and left subintestinal veins, which communicate with respective vitelline veins. Subintestinal veins anastomose below gut, just posterior to vitelline duct. Left subintestinal vein larger than right. Both can be traced backward to cloaca.	Like preceding stage (No. 18).	—	19

No.	Designation	Size	Preparation Data	Body Form	Somites
20	H.E.C. 1352	Embryo 5.2 mm.	Fixative: Aceto-corrosive. Section: Transverse, 6 μ. Stain: Iron haematoxylin, Congo red.	Embryo attached to blastoderm along nearly the middle third of its length. Slight dorsal flexure. Head bent nearly at right angles to dorsal line of body. Tail bent ventrally and ending in a distinct tail knob. Pericardial cavity forms distinct rounded swelling.	Thirty-five or thirty-six pairs of somites. Segmented mesoderm extends to posterior end of cloaca. In cardiac and vitelline duct regions, sclerotomes loosely mesenchymous and extend dorsally to base of neural canal. In same region, posterior border of myotome is fibrous.
21	H.E.C. 1637	Embryo 6.2 mm	Fixative: Aceto-corrosive. Section: Sagittal, 8 μ. Stain: Iron haematoxylin, Congo red.	No dorsal flexure. Mid-brain region projects forward beyond fore-brain region, which is bent backward at an angle of 30° to it. Tail flexed almost at right angles to trunk. Tail knob not well marked.	Fifty or fifty-one pairs of somites.
22	H.E.C. 1503	Embryo 7.5 mm.	Fixative: Aceto-corrosive. Section: Transverse, 6 μ. Stain: Iron haematoxylin, orange G.	Mid-brain region bent at right angles to pharyngeal. Fore-brain region bent a little posteriorly from mid-brain region. Antero-posterior diameter of yolk stalk one-fourth length of embryo. A very slight dorsal flexure over yolk stalk region. Small tail knob.	Fifty-three or fifty-four pairs of somites (counted from sections). Segmented mesoderm extends beyond cloaca. Sclerotomes of last ten somites not yet formed.
23	H.E.C. 1495	Embryo 9.0 mm.	Fixative: Aceto-corrosive. Section: Transverse, 8 μ. Stain: Iron haematoxylin, orange G.	Antero-posterior diameter of yolk stalk one-fifth length of embryo. Mid-brain region bent at right angles to pharyngeal. Fore-brain bent at an angle of about 45° to mid-brain region. Fairly prominent tail knob.	Sixty-three pairs of somites (counted externally). Segmented mesoderm extends nearly to neurenteric canal. Sclerotomes of last sixteen somites not yet formed.
24	a) H.E.C. 206 b) H.E.C. 208 c) H.E.C. 207	Embryo 11.5 mm.	a) Fixative: Aceto-corrosive. Section: Transverse, 10 μ. Stain: Borax carmine. b) Fixative: Aceto-corrosive. Section: Sagittal, 10 μ. Stain: Borax carmine. c) Fixative: Aceto-corrosive. Section: Frontal, 10 μ. Stain: Borax carmine.	Fore-brain region flexed until original antero-posterior axis lies in transverse plane. Distinct 'twixt-brain swelling. Sharply outlined branchial plate. Beginning of mid-lateral line. Pericardial chamber dilated. Cloaca forms prominent ventral swelling.	Sixty-five pairs of somites in a cleared embryo of the same size and stage. Somites anterior to pancreas not in contact with coelom wall ventrally. Somites in posterior trunk region attached to coelom wall by a narrow solid stalk.
25	a) H.E.C. 223 b) H.E.C. 224 c) H.E.C. 226	Embryo 13.0 mm.	a) Fixative: Picro-sulphuric. Section: Transverse, 10 μ. Stain: Alum cochineal. b) Fixative: Picro-sulphuric. Section: Sagittal, 10 μ. Stain: Alum cochineal. c) Fixative: Picro-sulphuric. Section: Frontal, 10 μ. Stain: Alum cochineal.	Fore-brain swelling farther expanded ventrally than in preceding stage (No. 24). Mid-lateral line distinct from branchial plate backward to a point midway between cloaca and tail.	Seventy-one pairs of somites in a cleared embryo of the same length and stage.
26	a) H.E.C. 227 b) H.E.C. 229 c) H.E.C. 228	Embryo 15.0 mm.	a) Fixative: Picro-sulphuric. Section: Transverse, 10 μ. Stain: Alum cochineal. b) Fixative: Picro-sulphuric. Section: Sagittal, 20 μ. Stain: Alum cochineal. c) Fixative: Picro-sulphuric. Section: Frontal, 16 μ. Stain: Alum cochineal.	Entire head region bent a little ventrally from pharyngeal region. Anterior and posterior dorsal fins differentiated from dorsal fin fold. Pectoral fin fold present. Wide ventral fold of caudal fin. Prominent cloacal protuberance.	Eighty-six pairs of somites in a cleared embryo of the same length and stage. Anterior trunk somites extend into upper part of lateral body wall. Somites connected with coelom wall from level of third turn of spiral valve posteriorly.

Head-Somites	Notochord, Subnotochordal Rod, Axial Skeleton	Ectoderm in early Stages	No.
Lumen of premandibular somite circular in cross section, extends backward to tip of pharynx. Median connecting stalk broad anteriorly, tapering posteriorly. Dorsal wall epithelial, remainder mesenchymous. Two small cavities in stalk on either side of median line. A distinct lumen in anterior somite dorsally.	Anterior tip of notochord slightly recurved. Central cluster of nuclei, as described for preceding stages (Nos. 17 and 18), in head and posterior trunk region. In anterior trunk region, nuclei more generally scattered and smaller in size. From level of cloaca backward, the primitive cellular condition of notochord still present. — A separate anterior segment of subnotochordal rod springs from roof of pharynx near its anterior tip and extends forward just under notochord to its ventral curve. Second segment a ridge on dorsal surface of pharynx from level of first gill slit to middle heart region. Extends backward to cloaca as a free rod lying between two dorsal aortae. Fused with entoderm at cloaca.	—	20
Distinct lumina in premandibular somite. Anterior somite connected with premandibular on either side by a strand of thickened mesenchyma. Proliferation of mesenchyma from mesial wall of hyoid somite. Hyoid somite separated from fourth head somite by a deep lateral groove.	Anterior end of notochord bent ventrally at an angle of 90°. In contact but not attached to median stalk of premandibular somite. Nuclei of notochord generally scattered from level of facial nerve backward to posterior trunk region. In other parts of notochord, cells arranged in central cluster. — No anterior segment of subnotochordal rod.	—	21
Anterior somite extends nearly to cranial end of mandibular somite; its mesial wall fused with lateral wall of premandibular somite. Premandibular somite triangular in cross section, the two lateral cavities connected by a broad dorsal and a minute ventral stalk. From the dorso-median stalk two small blind pouches extend posteriorly. Posterior end of hyoid somite divided into dorsal and ventral processes.	Anterior end of notochord a little recurved, in contact but not fused with median stalk of premandibular cavity. Notochord 120 μ in diameter in largest part. Central cluster of nuclei at extreme anterior end, and from level of anterior end of cloaca backward, nuclei in trunk region gathered at the periphery of notochord. — Subnotochordal rod arises as in preceding embryos (Nos. 20 and 21), fuses with entoderm again just posterior to cloaca. In posterior part of free portion is increased in size until one-half diameter of notochord.	—	22
Anterior somite almost circular in cross section; walls epithelial and thick, with two rows of nuclei ventrally and mesially. Extends slightly in front of premandibular cavity. Posterior wall fused with premandibular, but no communication of cavities. Premandibular somite much larger than in preceding stages; lateral portions connected by a single median stalk, the lumen of wich is extremely small at the median line. Three irregular chambers bud off dorsally from this stalk. A small process with distinctly epithelial walls extends from the dorso-lateral angle of the mandibular somite, between the root of the semilunar ganglion and the hyoid somite. Ventral mesial angle of hyoid head somite decidedly mesenchymous.	Anterior end of notochord recurved for 24 μ (by sections). In cardiac and hepatic regions, cells arranged in a fairly definite epitheloid layer at periphery of notochord. — Subnotochordal rod attached anteriorly to roof of pharynx between third and fourth gill pouches, posteriorly to postanal gut just behind cloaca. Much reduced in size in pharyngeal region.	—	23
Lateral parts of premandibular somite connected by broad median stalk containing a large lumen, which is prolonged backward as an irregular pocket. Walls of anterior, premandibular and mandibular somites in contact above eye, but not fused.	Anterior end of notochord recurved for 50 μ (by sections). Recurved part in contact with median stalk of premandibular somite. Notochord 150 μ in diameter in largest part (region of yolk stalk). Cells generally scattered in head region backward to third gill slit. From this level backward to anterior end of cloaca, cells flattened against elastica. Cells gathered in central cluster or central ring from posterior end of cloaca to end of notochord. — Subnotochordal rod entirely detached from gut. In contact but not fused with entoderm over third gill slit. Extends backward behind cloaca.	—	24
Anterior somite elongated, narrow, lying anteriorly in a groove in lateral wall of premandibular somite and posteriorly in the angle between premandibular and mandibular somites. On the left side, lumen of anterior head somite opens into that of the premandibular somite by a channel 50 μ in diameter. Median stalk of premandibular somite much compressed between infundibulum and notochord (see note under latter). A large pocket extends upward from the mesial surface of the mandibular cavity, and is separated from it anteriorly by the root of the trigeminal nerve. "Muscle E" *) represented by a thickening at the end of this pocket? Hyoid cavity distinctly bi-lobed posteriorly.	Anterior end of notochord recurved for 110 μ (by sections). Broadly oval in cross section. Nuclei throughout notochord flattened against elastica. — Subnotochordal rod extends from first gill slit nearly to posterior end of notochord. At level of second gill slit, approaches roof of pharynx but is not fused with it. A distinct median ridge on pharynx at this point. Average diameter of subnotochordal rod 15 μ.	—	25
No communication between lumina of anterior somites and of premandibular somite. Processes of premandibular somite which go to form inferior oblique muscle and inferior rectus muscle distinct. Anterior process (anlage of superior oblique muscle) of mandibular somite extends as far cranially as anterior wall of optic vesicle, "Muscle E" process distinct.	Anterior end of notochord sharply recurved for 150 μ. Broadly oval in cross section in trunk region; vertical diameter 180 μ, transverse diameter 150 μ. Elastica much thickened. — Subnotochordal rod in contact with roof of pharynx over third gill slit.	—	26

*) The nomenclature of A. Lamb (Amer. Journ. Anat., I, 1901, 185), has been followed in descriptions of rudimentary eye muscles.

No.	Brain, and Cephalic Nerves	Hypophysis and Infundibulum
20	Cranio-caudal axis of fore-brain a little greater than vertical. A shallow recessus neuroporicus present. Skin and neurectoderm fused for 18 μ (by sections), in median line, anterior to recessus. Distinct recessus postopticus and recessus praeopticus. Mid-brain a little dilated; broader ventrally than dorsally; separated from fore-brain externally by shallow lateral grooves. Roof of hind-brain composed of a single layer of columnar cells. Lateral walls much thickened, with as many as six rows of nuclei in thickest part. At origin of trigeminus, ventricle kite-shaped in cross section; in region of otocyst and posteriorly, hour-glass-shaped in cross section. — Connection between trigeminal crest and urtrochlearis more slender and irregular in outline. Ophthalmic portion of trigeminal crest lies in groove between optic vesicle and fore-brain; fused with skin ectoderm above optic vesicle; connected with the small thalamic crest by a slender strand, one cell thick. Facial and acoustic ganglia differentiated. Facial crest extends down dorsal half of second gill arch. Glossopharyngeal crest disconnected from both vagus and facial crests; extends down dorsal half of third gill arch. Anterior end of vagus crest much enlarged ventrally; divided into first and second branchial branches. A blunt process extends backward 30 μ from ventral posterior angle. Crest broadly continuous with spinal nerve crest dorsally.	Ventral surface of fore-brain in contact with thickened hypophyseal plate of epithelium. No invagination of hypophysis.
21	Axis of fore-brain bent a little caudal from that of mid-brain. Skin and neurectoderm fused for nearly 70 μ along median line at anterior neuropore. Very shallow recessus praeopticus and recessus postopticus. Beginning of tuberculum posterius? Mid-brain bent almost at right angles to hind-brain. Almost circular in cross section. Lateral walls of hind-brain very much thickened. Ventral half of canal reduced to a narrow slit between them. Ventral expansion of canal entirely absent anterior to otocyst, — very slight behind otocyst. — Thalamic crest disconnected from trigeminal. Urtrochlear connected with trigeminal crest by a broad band on the right, and a very small one on the left side. Distinct thickening of trigeminal crest above optic vesicle (anlage mesocephalic ganglion). Epibranchial and dorso-lateral placodes of facial established. Dorso-lateral placodes of glossopharyngeus and vagus established.	Hypophyseal plate in contact with brain wall at median line, from recessus praeopticus nearly to tuberculum posterius. Posterior (upper) end invaginated, forming a shallow pocket, the cranial end of which is in contact with tip of notochord.
22	Cranio-caudal and vertical diameters of fore-brain about equal. Shallow recessus praeopticus and recessus postopticus. Mid-brain separated externally from fore- and hind-brain by well defined but shallow grooves. Walls, floor, and roof of mid-brain of equal thickness. Hind-brain approximately four times as long as broad. Greatest transverse diameter in region of otocyst. Lateral walls, at origin of trigeminus, flattened until lying almost in transverse plane. Slight indication of division into dorsal and ventral zones in this region. Floor plate a single layer of elongated cells. No ventral enlargement of canal anterior to origin of vagus. — Urtrochlear and thalamic crests completely separated from trigeminal. Urtrochlear crest present in four sections of 6 μ only. Trigeminal crest attached to middle third of medullary tube; expanded above optic vesicle; extends down dorsal half of mandibular arch. A long slender strand of cells (urtrochlear process) extends forward and upward from anterior edge of trigeminal crest, towards urtrochlear crest. Epibranchial placode of glossopharyngeus established.	Posterior (upper) end of hypophysis extends forward from mouth 48 μ (by sections). Triangular in cross section. In contact with floor of fore-brain anteriorly, and with walls of lateral chambers of premandibular somite laterally.
23	Vertical diameter of fore-brain vesicle approximately three-fourths of cranio-caudal. In the median line, floor and roof of about equal thickness. Lateral walls approximately twice as thick as floor or roof. A very shallow recessus neuroporicus. Brain wall and skin ectoderm in contact, but not fused, in front of recessus. Recessus praeopticus and recessus postopticus barely distinguishable at median line. Distinct recessus mammillaris. Tuberculum posterius appears, at the median line, as a broadly U-shaped fold of the floor of the fore-brain. Roof of hind-brain widely expanded — composed of a single layer of squamous cells. Lateral walls very much thickened and in otic region almost in contact. A very narrow peripheral layer of ectoglia ventral to origin of trigeminus. — Thalamic crest entirely absent. No connection between urtrochlear and trigeminal crest. Trigeminal crest constricted into an anterior (ophthalmic) and a main posterior portion. Slender urtrochlear process. Mesocephalic ganglion lies over optic cup, — increased in size in comparison to preceding stage. Facial crest extends ventrally to middle of hyoid arch, as do glossopharyngeal and first and second branches of vagus crest. Third branch of vagus crest extends ventrally into dorsal end of sixth branchial arch. Epibranchial placodes of first and second branches of vagus crest established.	Small but distinct recessus mammillaris and tuberculum posterius. Hypophysis in contact with brain wall from posterior wall of mammillary recess forward nearly to recessus praeopticus. Cranial wall in contact with median stalk of premandibular somite.
24	Cranio-caudal diameter of telencephalon about an eighth greater than vertical. No distinct recessus neuroporicus. Distinct recessus praeopticus — brain wall thickened cranial to it. Shallow, indistinct recessus postopticus. Brain wall thickened between it and recessus praeopticus. Tuberculum posterius a little more prominent than in preceding stage — in mid-sagittal section shaped like a much flattened W. For processus mammillaris see infundibulum. Diencephalon broadly oval in cross section, — lateral walls nearly twice as thick as roof or floor. Distinct velum transversum — V-shaped in section. Distinct but small, post-velar arch and pinealis, the latter directed posteriorly. Mid brain broadly oval in cross section — floor and walls twice as thick as roof. A shallow sulcus limitans, extending from anterior of origin of trigeminus to origin of facial nerve, and from the middle of otocyst region to origin of glossopharyngeal nerve — absent in anterior half of otocyst region. Formation of cinerea beginning throughout length of myelencephalon. Narrow peripheral layer of ectoglia in ventral zone. — Urtrochlear crest entirely absent. Terminal nerve represented by a few cells connecting fore-brain with nasal epithelium? Oculomotor nerve extends backward to mesocephalic ganglion. Long slender urtrochlear process of trigeminus. Distinct mesocephalic ganglion. The two above structures connected with trigeminal ganglion by slender ganglionic cord. Short mandibular and maxillary rami of trigeminus. Slight differentiation of acoustic, hyomandibular, and superficial ophthalmic portions of facial-acoustic ganglion. Short buccal and superficial ophthalmic rami — placodes of each established. Epibranchial placode of facial nerve established. Hyoid ramus of facial nerve in dorsal third of hyoid arch. Dorso-lateral and epibranchial placodes of glossopharyngeus established. First, second, and third branchial rami of vagus. Epibranchial and dorso-lateral placodes of each formed. Lateral ramus extends backward a little beyond posterior end of pharynx.	Posterior, i. e. invaginated part, of hypophysis 0.2 mm. in length at median line. Expanded distally. Anterior part extends forward to recessus postopticus.
25	Telencephalic vesicle enlarged and elongated, as compared with preceding stage. Cranio-caudal diameter nearly twice vertical. A distinct though shallow recessus neuroporicus present. Recessus praeopticus laterally deeply V-shaped in cross section, shallow at median line. Recessus opticus distinguishable only at median line. Velum transversum twice as long (100 μ) at the median line as in preceding stage (No. 24); epithelial walls in contact. Distinct post-velar arch. Pinealis extends backward slightly over roof of diencephalon. — Urtrochlear process of trigeminal ganglion absent. Anlage of ciliary ganglion attached by a few strands to distal end of oculomotor nerve, and by a broad cellular cord to mesocephalic ganglion.	Recessus mammillaris slightly recurved above tuberculum posterius. In contact anteriorly with median stalk of premandibular somite; posteriorly, with distal extremity of hypophysis. Invaginated (posterior) portion of hypophysis approximately 0.3 mm. in length. Anterior wall nearly twice as thick as posterior.
26	Vertical diameter of telencephalon three-fifths of cranio-caudal. Lateral walls of telencephalon over twice as thick as floor. Floor twice as thick as roof. No distinct recessus neuroporicus. Recessus praeopticus shallowly V-shaped at the median line — walls much thickened anterior and posterior to it. A very narrow peripheral band of ectoglia just posterior to recess. Velum transversum 300 μ in length at median line, a thin layer of mesenchyma between epithelial walls. Superior commissure represented by a narrow peripheral band of ectoglia just anterior to pinealis. Pinealis 120 μ in length at median line. Posterior commissure a broad peripheral layer of ectoglia. Ventral zone of lateral walls of mesencephalon a little thickened. A narrow ectoglic layer at base of ventral zone. Anlage of cerebellum a distinct thickening of roof or anterior end of hind-brain. Broad shallow sulcus limitans, extending entire length of hind-brain. Distinct formation of cinerea ventral to origin of trigeminal and facial nerves. Broad band of ectoglia on either side of floor plate throughout length of hind-brain. Distinct sensory bundles of trigeminal and facial nerves. — Olfactories established. Deep ophthalmic ramus of trigeminus extends forward nearly to ventral edge of optic cup. Mesocephalic ganglion much larger. Connected on its mesial surface, by a few cellular strands, with a very small ciliary ganglion. Connected by a broad cellular band with trigeminal ganglion, — superficial ophthalmic ramus of trigeminus a small branch arising from the anterior surface of this band. Superficial ophthalmic ramus of facial extends forward a little beyond anterior edge of trigeminal ganglion. Three branchial rami of vagus — fourth forming. Visceral ramus of vagus extends posteriorly to anterior end of oesophagus. Lateral line ramus extends backward to middle of cardiac region.	Recessus mammillaris recurved a little dorsal to tuberculum posterius. Recessus infundibuli a very shallow depression in floor of infundibular region, caudal to recessus mammillaris. Posterior part of hypophysis approximately 0.4 mm. in length. Transverse diameter of proximal end of sac two-thirds that of distal. Walls in contact at proximal end.

Spinal Chord, Spinal Nerves, Sympathetic	Eye	Nose	No.
Cord much as in preceding embryo (No. 19). Ventral halves of lateral walls almost in contact in posterior trunk region. In anterior trunk region, lateral walls two to three times as thick as roof or floor plate. Neural crest extends backward nearly to posterior wall of yolk stalk. Three (?) distinct ganglionic enlargements posterior to vagus.	Ectoderm of lentic plate 30 μ thick over optic vesicles, rather sharply marked off from skin ectoderm. Optic vesicles connected with fore-brain for one-fifth of their cranio-caudal diameter, and one-third of the dorso-ventral diameter. Cranial two-fifths of vesicles project forward as blind pouches.	Nasal placodes a little depressed, and lie mainly anterior to optic vesicles.	20
Cord in greater part of trunk region broadly oval in cross section; transverse diameter about three-fourths of vertical. Ovate in cross section in tail region. Neural crest extends posteriorly to twenty-sixth segment (about midway between posterior wall of yolk stalk and cloaca). Division of crest into separate ganglia anlagen except at extreme posterior end. Ventral roots present in anterior trunk region. Ganglia anlagen and ventral roots not joined.	Lentic plate 50 μ thick; mesial surface slightly convex. No lentic pit. Optic cup 0.35 mm. in diameter. Stalk one-half diameter of cup. Lateral wall of cup nearly twice as thick as mesial.	Like preceding stage (No. 20).	21
Cord oval in cross section; nearly as broad as high in trunk region. Middle third of walls in contact in anterior trunk region. Many mitoses. Twenty-eight spinal ganglia. Two occipital ganglia, which appear as enlargements of the ganglionic cord connecting the vagus with the spinal nerve crest. Ventral roots of occipital and first eighteen spinal nerves present. Dorsal and ventral roots not connected. Dorsal roots in region of pronephros and pancreas extend a little below level of dorsal surface of notochord. Neural crest extends posteriorly to level of cloaca.	Lentic epithelium 80 μ thick, containing three rows of nuclei. Deep lentic pit. Optic cup 0.38 mm. in diameter. Cavity between mesial and lateral walls large. Lateral wall twice as thick as mesial. Optic stalk one-half diameter of optic cup.	Distinct depression of nasal pits. Epithelium approximately three times as thick as skin ectoderm. Many mitotic figures in outer border.	22
Cord as in preceding embryo (No. 22). Circular in cross section from cloaca backward. Thirty-six spinal ganglia (by sections). No definite ganglia beyond anterior end of cloaca. Ventral roots and ganglia of nerves anterior to posterior wall of yolk stalk united. Longest nerves (in region of pancreas) extend ventrally to level of aorta.	Lens almost spherical, 100 μ in diameter, four or five rows of closely packed nuclei, and many division figures. Lens still broadly attached to ectoderm. Lentic pit deeply V-shaped in cross section. Optic cup pressed against mesial surface of lens. Lumen of optic vesicle a narrow cleft. Lateral wall 90 μ thick; mesial wall 30 μ thick; four rows of nuclei in lateral wall. Optic stalk nearly one-half diameter of cup.	As in preceding embryo (No. 22), except that transition from nasal to skin epithelium is more sharply marked ventrally.	23
Vertical diameter of cord in trunk region, approximately 0.25 mm. Transverse diameter three-fourths of vertical. Floor plate three times as thick as roof plate; lateral walls twice as thick as floor plate. Canal a narrow vertical slit, expanded ventrally and a little dorsally. A narrow lateral layer of ectoglia in anterior trunk region. Fifty-one spinal ganglia (by sections). Nerves in anterior trunk region extend ventrally to level of dorsal wall of aorta. Beginning of dorsal rami in this region.	Lens completely cut off from skin ectoderm, although pressed against it. Diameter 0.3 mm. (by sections). Cavity irregular, often star-shaped in cross section. Division figures frequent. Mesial wall a little thicker than lateral.	Depressions a little deeper than in preceding stage (No. 23).	24
Vertical diameter of cord in trunk region, approximately 0.28 mm. In greater part of trunk region, transverse diameter but little less than vertical. Sympathetic ganglia small masses of cells on mesial sides of nerves of anterior trunk region at the level of dorsal aorta.	Lens flatly convex laterally, slightly concave mesially. Greatest breadth 0.38 mm., greatest thickness 0.22 mm. Mesial wall three times as thick as lateral, containing three to four rows of nuclei. Optic stalk one-third as broad as optic cup, nearly circular in cross section. Retinal wall of cup six times as thick as chorioid.	Nasal pits shallow, ventral edges sunk in at right angles to the surface of the head. Epithelium thickest and slightly incurved at ventral angle of pit. Epithelium approaches brain, but is separated from it by a little mesenchyma.	25
In cardiac region, cord 0.35 mm. in vertical diameter. In pancreatic region, 0.25 mm. in vertical diameter. Transverse diameter almost equal to vertical. Transverse diameter of canal approximately one-fifth of vertical. Lateral walls in contact in pharyngeal and cardiac regions. Neurenteric canal still present, but constricted. Narrow peripheral layer of ectoglia in lateral walls of cord — thickest ventrally. Beginning of formation of cinerea in ventral half of cord in anterior trunk region. Interganglionic cord broken down in anterior trunk region; still continuous from the 17th spinal ganglion backward. Spinal nerves of anterior trunk region directed somewhat posteriorly. In pancreatic region, extend ventrally into somatopleure of body wall. Sympathetic ganglia more definite than in preceding stage (No. 24).	Lens flatly oval in cross section; greatest breadth 0.46 mm., greatest thickness 0.3 mm. Mesial wall of lens seven times as thick as lateral wall. Lentic cavity elongately crescentic in cross section, as wide as lateral lens wall. Retinal wall of optic cup eight times as thick as chorioid. Many division figures in inner zone. Mesenchyma and hyaloid artery extend through chorioid fissure and just enter optic cup.	Deepest part of nasal pit is almost semicircular in cross section. Line between nasal and skin epithelium sharply marked ventrally, less so dorsally. Olfactory nerve in contact with nasal epithelium at the ventral angle of the bottom of pit.	26

No.	Ear	Integument, Lateral Line	Mouth	Archenteron
20	Otic pit invaginated anteriorly and a little dorsally, forming a deep pocket which is flattened laterally. Open part of otic pit broadly oval in outline, gradually flattening out posteriorly. Invaginated part of otic pit lies over anterior end of first gill pouch.	Like preceding stage (No. 19).	Oral plate broken through anteriorly for 60 μ (by sections). Very thin posteriorly.	—
21	Otocyst 300 μ in length. Vertical diameter equal to two-thirds of length. Posterior third forms a broad neck connected with the skin ectoderm.	—	Oral cleft 200 μ in length (by sections). 40 μ in width in broadest part.	—
22	Otocyst two-thirds as high as long. In thickest part two-thirds as broad as high. Connected with ectoderm by a neck occupying upper half of approximately the posterior third of outer wall. This neck directed slightly posteriorly and succeeded by a shallow groove in the thickened skin ectoderm.	Much as preceding stages (Nos. 19 and 20), except for placodes (see cranial nerves).	Mouth opening an elongated oval slit, approximately four times as long as broad.	—
23	Otocyst nearly three fourths as high as long.	Pharyngeal plate of epithelium sharply marked off from general skin ectoderm dorsally, less so ventrally; 65 μ thick in thickest portion. 2—4 rows of nuclei. Extends posteriorly for 0.25 mm. (by sections) beyond last gill slit. Ectoderm over lower part of head 20 μ in thickness.	Mouth opening oval in outline, three times as long as broad.	—
24	Otocyst extends through fifty-seven sections of 6 μ, bluntly rounded posteriorly, roundly pointed anteriorly, flatly rounded below. Ductus endolymphaticus arises from a broad funnel-shaped base, extends first dorsally, then dorso-posteriorly, fusing with skin above posterior end of otocyst.	A single layer of cuboidal or columnar cells over head ventral to supra-orbital placode. In trunk region, a single layer of squamous or low cuboidal cells, except over fin folds. Pharyngeal plate sharply marked off from general epithelium dorsally. Supra-orbital, infra-orbital, mandibular, and lateral-line placodes established.	Mouth opening broadly oval in outline, reduced to a narrow cleft posteriorly. Anterior (dorsal) halves of mandibular arches bent mesially and enlarged.	—
25	Otocyst much the same as in preceding stage (No. 24).	Much as preceding stage (No. 24).	Much as preceding stage (No. 24).	—
26	Otocyst 120 μ in length (by sections); greatest vertical diameter one-half of length, transverse diameter one-half of vertical. Epithelium of mesial and ventral walls much thicker than that of dorsal and lateral. Ductus endolymphaticus arises from the middle third of the dorsal surface of otocyst, on the median side. It extends almost directly posteriorly, fusing with skin slightly in front of posterior wall of otocyst.	Epithelium consists mainly of one layer of cells; two layers of cells on ventral surface of head, on sides and ventral surface of trunk. Pharyngeal plate much less definitely outlined than in preceding stages.	Mouth opening diamond-shaped in outline, almost as broad as long. Mandibular and maxillary processes bent at an angle of approximately 90°. Anterior ends of maxillary processes much enlarged — separated at median line by a cleft approximately one-third the width of the mouth opening. Very slight frontal process.	—

Pharynx, Thyreoid, Thymus, Suprapericardial Body	Digestive Tube	Liver, Pancreas, Spleen	No.
Pharynx more elongated than in preceding stage (No. 19). Upper part of first gill slit open, and where not open the ectoderm and entoderm are fused. Second gill slit a minute round opening; ectoderm and entoderm fused for some distance on either side of this opening. Thyreoid a small shallow open pouch at postero-ventral angle of pharynx.	Oesophagus much longer than in preceding stage (No. 19), tapering posteriorly, in narrowest portion broadly oval in outline. Lumen much reduced in size, about one-fifth diameter of tube.	Much as preceding embryo (No. 19). Anterior wall of pouch better defined.	20
First and second gill slits open dorsally. Ectoderm fused with entoderm over third and fourth pouches. Thyreoid as in preceding stage.	Oesophagus broadly oval in cross section; vertical diameter a little greater than transverse. Posterior walls much thickened and lumen reduced to one-seventh diameter of tube. About two-thirds of a complete turn of spiral valve.	Liver pouch expanded laterally. Walls almost twice as thick as those of gut. Pancreas a small elongated diverticulum from dorsal wall of gut over yolk stalk. Directed posteriorly, and expanded laterally at its posterior end.	21
Dorsal halves of first and second gill slits open. Ectoderm and entoderm of third and fourth gill slits fused. Thyreoid projects backward 24 μ (by sections) beyond the ventro-posterior angle of pharynx. Walls of thyreoid pouch in contact.	Oesophagus constricted posteriorly, almost circular in cross section. In narrowest part, lumen barely visible; less than one-tenth diameter of gut. Vitelline duct approximately equal to one-fifth length of gut from pharynx to neurenteric canal. One and one-third turns of spiral valve. Cloaca dilated: about twice the diameter of preceding intestine. Ectoderm and entoderm, on ventral surface, in contact for 120 μ (by sections). Gut constricted immediately behind cloaca, but dilated anterior to neurenteric canal.	Liver an elongated ventral pouch constricted a little transversely at its connection with gut. Distinct lateral outpouchings from posterior end of ventral pouch. Anlage of gall bladder, a depression in posterior end of floor of ventral pouch, — continuous with anterior wall of vitelline duct posteriorly. Posterior end of pancreas projects backward over dorsal wall of gut for 25 μ (by sections).	22
Dorsal halves of first and second gill slits open. Dorsal third of third slit open. Ectoderm and entoderm fused over fourth pouch and broken through for one section of 8 μ on either side. Fifth gill pouch established. Thyreoid pouch 80 μ in length: posterior third not attached to floor of pharynx.	Oesophagus circular or broadly oval in cross section. Lumen in posterior half very minute. Antero-posterior diameter of vitelline duct 250 μ (about one-sixth of length of gut from pharynx to neurenteric canal). A distinct groove on the left wall of vitelline duct from liver diverticulum to posterior end of duct. One and two-thirds turns of spiral valve. Post-cloacal gut much constricted anteriorly, but dilated before joining neurenteric canal.	Liver evagination four times as broad as gut connected with it. In its widest part, four times as broad as high. Connection between gut and liver slightly constricted laterally. Gall bladder, a ventral pouch from liver invagination, about 130 μ in length, sharply marked off anteriorly but broadly connected with liver above and merging with yolk sac posteriorly. — Pancreas a little larger than in preceding stage (No. 22). Twice as broad as gut with which it is connected. Connected with dorsal wall of gut for almost entire length of pouch. Epithelium of pouch twice as thick as that of gut.	23
First four gill slits open. Fifth pouch well established, with ectoderm and entoderm in contact dorsally and fused ventrally. Sixth pouch well formed, with ectoderm and entoderm in contact. Three knob-like gill filaments on posterior wall of second gill slit. Thyreoid projects backward 70 μ (by sections) from ventro-posterior angle of pharynx.	Lumen in posterior part of oesophagus occluded for 250 μ (by sections). Oesophagus in cross section roundly oval anterior, and triangular posterior to closed portion. Four complete turns of spiral valve. Cloaca dilated — vertical diameter three times that of gut preceding it.	Lateral pouches of liver extend upward nearly to dorsal wall of gut, and are produced posteriorly. Connected with median portion along base of their anterior two-thirds. Several secondary outpocketings from anterior part of lateral pouches. Median chamber of liver evagination broadly connected with gut above it. Gall bladder a deep ventral pouch from median chamber. Pancreas projects backward over dorsal wall of gut for 100 μ (by sections). Attached part approximately the same length as free posterior part.	24
First three gill slits widely open. Fourth gill slit established, but arches still in contact. Ectoderm and entoderm in contact over fifth and sixth pouches. Thyreoid pear-shaped in cross section, 150 μ long (by sections), connected with pharyngeal epithelium for 20 μ at extreme anterior end, posteriorly well separated from pharynx.	Oesophagus closed for 170 μ (by sections). Transverse diameter of anterior part three times vertical. Solid portion circular or oval in cross section. Immediately behind the solid oesophagus (i. e. region of future stomach) gut dilated, broadly oval in cross section. Six and one-half turns of spiral valve. Behind cloaca gut reduced to a slender solid cord, which acquires a lumen and is a little dilated before passing over into neurenteric canal.	Median chamber (ductus choledochus) of liver evagination separated from gut anteriorly. Lateral pouches connected with median chamber by short wide ducts. Numerous secondary outpouchings from lateral pouches. Gall bladder expanded ventrally, attached to median chamber of liver along entire length by a transversely constricted neck. Pancreas attached to dorsal wall of gut by its anterior four-fifths.	25
Five anterior gill slits open. First slit very narrow ventrally. Ectoderm and entoderm fused and very thin for short distance over sixth pouch. Four small gill filaments on hyoid surface of second gill slit, two on mandibular surface. Thyreoid 250 μ in length (by sections) pointed anteriorly, broad and rounded posteriorly, attached to base of pharynx anteriorly by a constricted neck. A deep groove in floor of pharynx just above thyreoid.	Oesophagus solid for 150 μ (by sections). Stomach enlargement distinct — nearly twice diameter of solid oesophagus. Curved a little ventrally. Vitelline duct approximately one-tenth the length of gut from pharynx to cloaca. Gut folded over to the left of vitelline duct along the anterior two-thirds of their connection. Eight turns of spiral valve. Gut much constricted just anterior to cloaca. Lumen equal to one-sixth diameter of gut in this region. Cloaca ends abruptly posteriorly; no post-cloacal gut.	Outlines of original lateral pouches of liver obscured by the very numerous tubules formed from them. Lateral pouches communicate with median chamber (ductus choledochus) by narrow lateral openings 180 μ in length (by sections). Ductus choledochus, flattened at its distal end, extends 100 μ posterior to liver; roundly triangular in cross section in this part; approximately same calibre as gut. Opens into ventral wall of gut 200 μ (by sections) anterior to vitelline duct. Gall bladder 250 μ in length (by sections), attached along its middle three-fifths to ventral wall of ductus choledochus by a laterally constricted neck. Pancreas 300 μ in length (by sections), connected by its middle third with dorsal wall of gut. Formation of tubules on right side and roof.	26

No.	Urogenital System	Heart, Pericardium, Blood Vessels
20	Wolffian duct attached to three anterior pronephric anlagen, extends posteriorly for 73 sections of 6 μ as a solid cord of cells. Fused with ectoderm for last fourth of its length.	Posterior part of heart is strongly bulged dorsally and to the right. Anteriorly, dorsal mesocardium long and thin. Broken through over middle part of heart for 30 sections of 6 μ. Mesothelial layer of heart a little thicker than in preceding stage, being made up of cuboid or columnar cells. — Upper end of first aortic arch dilated (anlage of arteria ophthalmica magna). Vessels from dorsal and ventral aorta almost meet to form second arch. Pronephric arteries represented by three dilatations of the aorta on the right side in pronephric region. — Veins as in preceding stage (No. 19).
21	Four anterior pronephric tubules possess lumina and are connected with Wolffian duct. A minute lumen in Wolffian duct just posterior to third pronephric tubule — all other parts solid. Wolffian duct extends backward nearly to anterior end of cloaca.	Dorsal mesocardium only present at anterior and posterior ends of heart tube. — First and second aortic arches complete. The three pronephric arteries of right side united, forming vitelline artery which extends to blastoderm.
22	Wolffian duct connected with coelom by two pronephric funnels. A small lumen in Wolffian duct for 80 μ (by sections) posterior to last pronephric funnel; posterior to this point duct is solid. Duct ends blindly at anterior end of cloaca.	Heart shows slight differentiation into atrium, ventricle, and bulbus. Walls of ventricular chamber slightly thickened. Dorsal mesocardium attached only at posterior and anterior ends of heart. Somatic mesoderm and splanchnic mesoderm in contact above anterior ends of vitelline veins. — First two aortic arches complete. Branches from dorsal and ventral aortae to form third and fourth arches. Dorsal aorta extends backward as far as cloaca. It is a single vessel from level of fourth pharyngeal pouch backward — double at its extreme posterior end. Vitelline artery arises from two trunks. A small dilatation of dorsal aorta, posterior to second root of vitelline artery, represents third pronephric artery. — Anterior cardinal complex, as described for preceding stage (No. 21). Subintestinal vein single to cloaca. Left vitelline vein larger than right, connects with single subintestinal vein posteriorly. Right vitelline vein extends backward only to level of vitelline artery, no connection with subintestinal vein. A few corpuscles in the heart and dorsal aorta — irregular cells with large oval nuclei, containing one or two dark staining chromatin masses.
23	Five pronephric tubules, first separate, remainder forming canals connecting coelom with Wolffian duct. Lumen present in anterior part of Wolffian duct, about five sections of 8 μ only. Wall of duct thickest dorsally and mesially. About 15 nuclei seen in cross section. Duct extends posteriorly as far as extreme anterior end of cloaca, where it lies in contact with the ectoderm. Eight pairs of mesonephric tubules clearly established. They are broadly continuous with coelomic epithelium, and not in contact with Wolffian duct.	Heart somewhat more twisted than in preceding stage. Ventricle lies below and to the left of atrium. Slight constriction of atrio-ventricular canal. A slight constriction also between ventricle and bulbus. Mesothelial wall of sinus venosus is fused for a short distance with the mesothelium of somatopleure. — First, second, and third aortic arches completely formed. Fourth and fifth represented by short sprigs. Dorsal aorta extends backward beyond cloaca. Vitelline artery arises from dorsal aorta by two roots of about equal size. — Vena capitis medialis connected with aorta as in preceding stages. Extends forward to dorsal surface of optic cup, and backward beyond posterior edge of vagus; at this point turns sharply ventrally, joining with anterior cardinal at level of aorta. Anterior cardinal extremely irregular, connected by numerous channels with aorta. Joins with posterior cardinal, forming common cardinal, at level of second spinal ganglion. Common cardinal extremely irregular; ends in capillary network in somatopleure, lateral to posterior end of heart; does not enter heart. Posterior cardinal can be traced backward a few sections only from juncture with anterior cardinal. Vitelline veins much as in preceding stage (No. 22). A recurrent branch from subintestinal and left vitelline vein passes dorsally to upper surface of gut, and thence forward to the right of the pancreas until almost meeting right vitelline vein. Subintestinal vein bifurcated posteriorly; its branches form a loop around cloaca, meeting on its dorsal surface to form a short caudal vein.
24	Wolffian duct extends backward as far as middle of cloaca; turned sharply downward at its extreme posterior end, and in contact with cloacal epithelium. A lumen present except in extreme posterior end. Twenty-six pairs of definite mesonephric tubules.	Ventricle lies mainly ventral to atrium. Atrio-ventricular canal connects anterior ends of atrium and ventricle — it descends directly downward and is sharply constricted. Sharp constriction also between sinus venosus and atrium. Splanchnic and somatic mesoderm lying on either side of sinus venosus fused for 200 μ antero-posteriorly (by sections). — Four aortic arches completely formed, fifth in process of formation. Aorta much dilated in region of fifth arch, bifurcated from level of posterior end of vagus forward. Two roots to vitelline artery, first root three times diameter of second. — Vena capitis medialis dilated above optic cup to form orbital sinus. Lies mesial to trigeminal, facial, glossopharyngeal, and vagus nerves, and otocyst. Communicates with anterior cardinal proper by two channels at level of vagus. Three segmental veins connect with anterior cardinal behind this junction. Common cardinals lie at level of solid oesophagus. Posterior cardinals extend backward to twentieth mesonephric tubule. Right and left vitelline veins communicate, posterior to pancreas. Right vitelline vein about half the size of left.
25	Anterior end of Wolffian duct at level of vitelline artery. Posterior end fused with lateral wall of cloaca. Twenty-nine pairs of mesonephric tubules.	Heart much as in preceding stage (No. 24). — Five aortic arches. Vitelline artery arises from two roots, anterior root slightly the smaller. Anterior cardinals and vitelline veins similar to those of preceding embryo (No. 25). Posterior cardinals lie mesial to Wolffian ducts: become extremely irregular posteriorly. Cannot be traced beyond thirtieth mesonephric tubule.
26	Wolffian duct opens anteriorly into coelom, just in front of pancreas. Posteriorly it is fused with wall of cloaca. Forty pairs of mesonephric tubules, the anterior three rudimentary. Tubules curved over dorsal surface of Wolffian duct. Interrenal organ a mass of condensed mesenchyma lying between aorta and radix mesenterica, extending from level of first turn of spiral valve to cloaca. 276 germ cells in genital region (WOODS).	Heart much elongated, ventricle projects far posterior to atrium. A constricted neck between atrium and sinus venosus. Walls of ventricle and bulbus much increased in thickness. Pericardial cavity closed from coelom dorsally, except for a narrow slit 230 μ long (by sections) lying to either side of the posterior part of the oesophagus. — Five anterior aortic arches complete. Dorsal and ventral sprouts almost meet to form sixth. First aortic arch much reduced in size at its base, but dilated below first gill slit. Small sprouts from upper ends of second, third, and fourth arches represent anlagen of afferent branchial arteries. Each sprout divides into a ventral and a dorsal limb. Capillaries from ventral limb of afferent vessel of second arch extend into till filaments.

Extremities	Remarks	No.
Median fold approximately as in preceding stage (No. 19), its free edge a little broader than base. Ventral fold higher than dorsal, extends anteriorly to cloaca.	Reconstructed. Fig. 9. General structure of head and pharyngeal region Fig. 19. Head somites.	20
Dorsal median fold 20 μ high in trunk region, 40 μ high in cloacal region. A little mesenchyma between dorsal surface of cord and skin ectoderm in anterior and middle trunk region.	—	21
Ectoderm of the sides of median fold separated a little anteriorly. Mesenchyma between dorsal surface of cord and skin ectoderm in anterior half of tail region. Posteriorly as in preceding stage. Fold highest over and of tail.	Reconstructed. Fig. 10. General structure. Cleared specimens of same stage used in preparation of descriptions of heart and brain.	22
Much as preceding stage (No. 22). In tail region, dorsal fold 40 μ high, ventral fold 80 μ high.	Reconstructed. Fig. 11. General structure of anterior half of embryo. Fig. 20. Head somites. Cleared specimens of same stage used in preparation of descriptions of heart, brain, and somites.	23
Ventral fold two to three times as high as dorsal. Anterior part of dorsal fold broadly V-shaped in cross section. Mesenchyma forms a slightly condensed mass between the ridge and dorsal wall of neural tube. On either side of the median line, epithelium two-layered. Posteriorly, the fold is as in preceding stage. Mesenchyma at base of ventral median ridge, condensed and increased in amount. Pectoral fin fold appears externally as a rounded horizontal ridge about 1.0 mm. in length, lying just posterior to branchial plate. Epithelium two-layered in this region. Considerable mesenchyma lying between it and body cavity mesothelium. Ventral ends of somites extend to dorsal end of fold. Somites enlarged at this point, with small ateral diverticula which represent beginning of primary muscle buds.	Reconstructed. Fig. 12. General structure of anterior half of embryo. Cleared and dissected specimens of same stage used in preparation of descriptions of heart, brain, digestive tract and somites. — Mouth described from specimen of same stage, but not of series. Literature: Minot, C. S., 1901, Morphology of the pineal region, based upon its development in Acanthias. Amer. Journ. Anat., I, 81—98, 14 figs. Woods, F. A., 1902, Origin and migration of the germ cells in Acanthias Amer. Journ. Anat., I, 307—320.	24
Pectoral fin fold approximately 1 mm. long, the posterior end directed a little ventrally. Middle three-fifths of the distal edge bent sharply ventrally. Epithelium much thickened over this edge. Mesenchyma increased in amount and much condensed. Ventral ends of somites extend into dorsal third of fin fold.	Cleared and dissected specimens of same stage used in preparation of descriptions of heart, brain, and digestive tract.	25
Anlagen of anterior and posterior dorsal fins as elevations of median fin fold. Between elevations, median fold much flattened. Pectoral fin approximately 1.5 mm. in length, its posterior end best defined and curved a little ventrally. Distal border increased in thickness. Distal edge turned sharply ventrally along most of its length. Epithelium two layered, inner layer of high columnar cells. Mesenchyma much thickened distally. Muscle buds expanded distally; anterior ones joined together by constricted mesothelial processes. Beginning of division of primary buds into secondary dorsal and ventral buds.	Reconstructed. Fig. 13. General structure. Fig. 14. Aortic arches. Cleared and dissected specimens of same stage used in preparation of descriptions of heart, brain, and digestive tract. — Mouth described from specimen of same stage, but not one of series. — External appearance of lateral line system described from specimen of same stage, but not one of series. Fig. 21. Digestive tract and heart of dissected specimen of same stage. Literature: Minot, C. S., 1901, Morphology of the pineal region. Amer. Journ. Anat. Woods, F. A., 1902, Origin and migration of the germ cells in Acanthias. Loc. cit.	26

No.	Designation	Size	Preparation Data	Body Form	Somites
27	a) H.E.C. 203 b) H.E.C. 204 c) H.E.C. 205	Embryo 18.0 mm.	a) Fixative: Aceto-corrosive. Section: Transverse, 10 μ. Stain: Borax carmine. b) Fixative: Aceto-corrosive. Section: Sagittal, 10 μ. Stain: Borax carmine. c) Fixative: Aceto-corrosive. Section: Frontal, 10 μ. Stain: Borax carmine.	Fore-brain region flexed posteriorly. Mid-brain swelling projects anterior to cranial edge of fore-brain: overhangs 'twixt-brain region slightly. Mid-lateral line extends almost to tail. Prominent cloacal protuberance.	Segmented mesoderm extends to tip of tail, last four or five somites undifferentiated. Myocoel confined to dorsal and ventral ends of somites in trunk region. Numerous myofibrils, a few of them apparently faintly cross striated. Anterior somites show distinct formation of ventral "hypoglossus musculature" processus.
28	a) H.E.C. 1494 b) H.E.C. 1493	Embryo a) 20.6 mm. b) 21.0 mm.	a) Fixative: Aceto-corrosive. Section: Transverse, 10 μ. Stain: Iron haematoxylin, Congo red. b) Fixative: Aceto-corrosive. Section: Sagittal, 10 μ. Stain: Iron haematoxylin, Congo red.	Fore-brain swelling directed a little anteriorly. 'Twixt-brain region obscured by the growth of fore. and mid-brains. Mid-brain and hind-brain swellings separated by a shallow groove. Prominent pelvic fin folds. Lateral line placode extends to level of pelvic fins.	Outline of somites (as see externally) flatly ≥-shaped. In region of pectoral fin, somites extend into ventral wall of body cavity. In mid-trunk region, somites extend through dorsal half of lateral walls of body cavity. A very small cavity in ventral and dorsal tips of somites. Division of somites into epiaxial and hypoaxial portions by a deep groove in the external surface at the mid lateral line. Dermatome distinct dorsally and ventrally, but broken down for some distance on either side of mid lateral line. Myoblasts distinctly cross striated. Last five or six pairs of somites undifferentiated.
29	H.E.C. 1492	Embryo 24.7 mm.	Fixative: Aceto-corrossive. Section: Transverse, 12 μ. Stain: Iron haematoxylin, Congo red.	Much like preceding embroyo (No. 28). Fore-brain swelling projects a little more anteriorly. Depression between mid-brain swelling and hind-brain deeper. Lateral line placode extends to middle of caudal fin.	Somites in mid-trunk region extend nearly to bases of lateral walls of body cavity. In same region, dermatome distinct only in dorsal third of epiaxial portion of segment and ventral three-fourths of hypoaxial portion. Small cavities in extreme dorsal and ventral ends of somites. Last six(?) pairs of somites but slightly differentiated.
30	a) H.E.C. 1357 b) H.E.C. 233 c) H.E.C. 221	Embryo 28.0 mm.	a) Fixative: Aceto-corrosive. Section: Transverse, 10 μ. Stain: Iron haematoxylin, orange G. b) Fixative: Picro-sulphuric. Section: Sagittal, 20 μ. Stain: Alum cochineal. c) Fixative: Picro-sulphuric. Section: Frontal, 20 μ. Stain: Alum cochineal.	Much like preceding embryo (No. 29). Fore-brain swelling projects farther forward. Depression between mid-brain and hind-brain swellings less marked.	Epiaxial and hypoaxial musculature almost divided. Dermatome distinguishable in approximately dorsal fifth of epiaxial, and ventral two-thirds of hypoaxial portion of somite in mid-trunk region.
31	a) H.E.C. 202 b) H.E.C. 362 c) H.E.C. 186	Embryo 34.0 mm.	a) Fixative: Aceto-corrosive. Section: Transverse, 20 μ. Stain: Borax carmine. b) Fixative: ZENKER's fluid. Section: Sagittal, 14 μ. Stain: Alum cochineal. c) Fixative: Aceto-corrosive. Section: Frontal, 20 μ. Stain: Borax carmine, iodine green.	Fore-brain swelling directed downward. Mid-brain swelling extends forward but little beyond it.	Arrangement of muscle bundles into cones quite distinct. Epiaxial and hypoaxial musculature almost completely separated. Muscle plates extend ventrally until nearly meeting in median ventral line. The dorsal and ventral tips of myotome and dermatome are still epithelial. No myocoel in tips of somites in trunk region.
32	a) H.E.C. 363 b) H.E.C. 176 c) H.E.C. 353	Embryo 37.0 mm.	a) Fixative: ZENKER's fluid. Section: Transverse 20 μ. Stain: Alum cochineal. b) Fixative: Aceto-corrosive. Section: Sagittal, 20 μ. Stain: Alum cochineal. c) Fixative: Picro-sulphuric. Section: Frontal, 14 μ. Stain: Alum cochineal.	Main divisions of brain obscured by increase of mesenchyma in head region. Short broad rostral process projects forward from ventral surface of head. Anlagen of dorsal fin spines.	Muscle cones more compactly arranged than in preceding stage (No. 31). Ventral epithelial tips of somites smaller. Dorsal epithelial tips obliterated in trunk region, anterior to point a little behind posterior dorsal fin.

Head-Somites	Notochord, Subnotochordal Rod, Axial Skeleton	Ectoderm in early Stages	No.
Much like preceding stage (No. 26).	Anterior end of notochord recurved for 50 μ (by sections), ending 40 μ anterior to hypophysis. The tip is separated from the median stalk of premandibular somite by a small cushion of cells containing many vacuoles. Mesenchyma slightly thickened about notochordal sheath in trunk region. — Subnotochordal rod one-eighth diameter of notochord in trunk region. — Parachordals represented by a very slight condensation of mesenchyma on either side of notochord, extending from anterior end of otocyst to glossopharyngeal nerve. This thickening extends laterally to mesial edges of ganglia.	—	27
Anterior somite appears as a slightly thickened mass of mesenchyma between premandibular somite and optic vesicle. Median stalk of premandibular somite very slender, perforated by a minute lumen. Lumen of hyoid somite obliterated; external and dorsal surfaces mesothelial, median and ventral surfaces fibrous. Middle third of hyoid somite (anlage of external rectus) extends ventrally and laterally to dorsal wall of optic vesicle.	Notochord recurved anteriorly for 100 μ, recurved portion very small. Division of sheath into elastica interna and externa. Mesenchyma much condensed about notochord, condensations on dorso-lateral angles to form neural arches. — Subnotochordal rod extends anteriorly to anterior limit of mouth, separated from notochord by little mesenchyma in pharyngeal region. One-fifteenth diameter of notochord in trunk region. — Parachordals extend forward to anterior edge of root of trigeminal nerve, posteriorly become indistinguishable from anlagen of neural arches. Mesenchymous in anterior fourth, precartilaginous posteriorly. Expanded laterally at otocyst. Beginnings of mesial and lateral processes about base of otocyst. First anlagen of alisphenoids as slight condensations of mesenchyma, extending from hypophysis to basal zone of hind-brain. Mandible, hyoid, and first branchial arch indicated by masses of slightly thickened mesenchyma.	—	28
Anterior somite entirely obliterated. Cavity of premandibular somite, except for lateral-ventral angle, filled with loose mesenchyma. Outline of premandibular somite barely distinguishable. Superior oblique distinctly cross striated. Adductor mandibulae faintly cross striated. Inferior rectus, inferior oblique, and muscle "F" fibrous.	Notochord nearly 0.5 mm. in diameter in anterior trunk region. Sheath as in preceding stage (No. 28). Neural arches in trunk region precartilaginous, extending dorsally to the middle of the spinal cord. Haemal arches represented by thin condensations of mesenchyma on either side of ventral half of notochord. Ribs represented by masses of thickened mesenchyma which extend laterally to mesial edge of somites. — Subnotochordal rod extends from second gill slit backward beyond cloaca. About one-twentieth diameter of notochord in trunk region. Surrounded by a definite non-cellular sheath. — Parachordals slightly expanded where joining alisphenoids. Posterior to exit of trigeminal nerve, appear in cross section as thin plates lying on either side of notochord, continuous with the thickened mesenchyma surrounding it. About as broad and one-sixth as thick as notochord. In region of otocyst, parachordals wedge-shaped in cross section, thicker portion lying laterally. Processes from parachordals extend dorsally on internal and external walls of otocyst, forming base of periotic capsule. Remainder of periotic capsule represented by thickened mesenchyma. Alisphenoids extend forward on either side of brain as thickened mesenchymal processes, as far as anterior edge of optic cup. Bases of alisphenoid plates precartilaginous posteriorly, end ventrally abruptly at level of oculomotor nerve. Posterior to this point they gradually slope inward, joining parachordals between exits of trochlear and trigeminal nerves. A thickened plate of mesenchyma, lying just below telencephalon, represents the rostrum. Posterior to the optic nerve, this plate is divided into two parts (the trabeculae), which extend upward on either side of infundibulum, and end in a precartilaginous thickening at dorsal surface of infundibulum. Slight thickenings beneath each optic cup represent ethmoid processes. Mandible, including processus palatino-basalis outlined in densely thickened mesenchyma, extends forward beyond posterior end of infundibulum. Hyoid and all branchial arches outlined in densely thickened mesenchyma.	—	29
Outlines of lateral portions of premandibular somite entirely obliterated. Median portion present as a small fibrous cord lying between infundibulum and recurved part of notochord. Cavity of mandibular somite obliterated. Inferior rectus, internal rectus, inferior oblique and adductor mandibulae muscles distinctly cross striated.	Notochord in trunk region approximately 0.5 mm. in diameter. Sheath 5 μ thick. Neural arches distinct condensations of mesenchyma, triangular in cross section, extending dorsally to middle of cord. Beginning of transverse processes as flattened thickenings of mesenchyma on ventral half of each side of notochord. Ribs ill defined thickenings of mesenchyma confluent with transverse processes proximally and extending distally to mesial edge of somites. — Parachordals much the same as in preceding stage (No. 29), extending somewhat farther laterally. Outer wall of otic capsule extends almost to dorsal surface of otocyst. Outer and inner walls attached to parachordals along middle third of capsule, and fused before and behind, enclosing otocyst. Alisphenoids much as in preceding embryo (No. 29) except that a larger portion of plates has become precartilaginous. Ventral processes of thickened mesenchyma extend downward on either side of diencephalon, half way to optic nerve. Rostral process faintly outlined in thickened mesenchyma; extends forward to anterior edge of nasal pit. Posterior to rostrum, trabeculae pass upward on either side of infundibulum, ending in slight enlargements just below parachordals. Posterior portion of trabeculae precartilaginous. Position of mandibular, hyoid, and first branchial arches indicated by condensations of mesenchyma.	—	30
—	A definite layer of sheath cells between inner and outer elastic sheaths of notochord dorsally and ventrally. Neural arches much as in preceding stage (No. 30). Transverse processes extend farther laterally. Rib anlagen attached to transverse processes by constricted mesenchymal thickenings. In mid-trunk region, ribs extend distally to inner edge of lateral ramus of vagus. — Subnotochordal rod, in trunk region, approximately one thirty-fifth diameter of notochord. — Alisphenoids extend upward over ventral two-thirds of mesencephalon. Precartilaginous ventrally, mesenchymous dorsally. Mesenchymous ventral processes from alisphenoids extend downward to level of optic nerve. Rostrum widely expanded, composed of thickened mesenchyma; extends forward to nasal pits. Ethmoid process represented by faint condensation of mesenchyma which extends as far forward as nasal pits; fused posteriorly with rostrum below eye. Constriction between rostrum and trabeculae proper very marked in region of optic chiasma, the connecting plate hardly wider than the neural tube above it. Trabeculae separate a short distance behind optic chiasma. Posterior ends of trabeculae extend upward on either side of hypophysis almost meeting parachordals, but not fused with them. Trabeculae precartilaginous posterior to optic chiasma. Mandibular, hyoid, and first three branchial arches outlined in thickened mesenchyma.	—	31
—	In trunk region, two or three layers of elongated notochordal sheath cells. Neural arches and transverse processes precartilaginous. A thin layer of precartilage surrounds notochord in anterior trunk region. Intercalary plates indicated by thickenings of mesenchyma? Ribs precartilaginous proximally: extend outward to lateral edge of musculature. — Subnotochordal rod barely distinguishable. — Alisphenoids meet over mid- and hind-brain. Their dorsal two-thirds thickened mesenchyma, remainder precartilage. Supraorbital ridge outlined in thickened mesenchyma. Rostrum extends forward to anterior edge of optic cup, forming a broad flat plate anteriorly and constricted to a narrow bar posteriorly. Trabeculae, except for posterior tips, fused along median line. Posterior ends fused with parachordals, thus enclosing caudal end of hypophysis. Visceral arches precartilaginous. Processus palatino-basalis of mandibular arch separated from trabeculae only by a little mesenchyma.	—	32

No.	Brain, and Cephalic Nerves	Hypophysis and Infundibulum
27	Cranio-caudal diameter of telencephalon almost twice vertical. Cranial end of telencephalon curved a little upward over diencephalon. A narrow peripheral layer of ectoglia dorsal and posterior to optic stalks. A few fibers in periphery of chiasma. Velum transversum 0.3 mm. in length at median line. Pinealis 0.1 mm. in length, dilated a little distally. Posterior and superior commissures as in preceding stage (No. 26). Mesencephalon nearly circular in section. Walls a little thickened ventrally. A narrow peripheral zone of ectoglia in ventral third of walls. Hind-brain much as in preceding stage. — Distinct superficial ophthalmic ramus of trigeminus arising near root of nerve. Mandibular and maxillary rami of trigeminus extend to bases of respective processes. Superficial ophthalmic ramus of facial extends forward as far as anterior edge of fore-brain. Hyomandibular division of facial-acoustic ganglion connected with general mass only at anterior end. Hyoid ramus extends to base of hyoid arch. Four branchial rami of vagus. Lateral line ramus extends posteriorly to level of pectoral fin.	Recessus infundibuli a distinct depression, semi-elliptical in sagittal section, extending dorsally a little on cranial end of hypophysis. Lateral edges of anterior part of hypophysis invaginated.
28	Cranio-caudal diameter of telencephalon almost twice vertical. Walls nearly 0.2 mm. thick. Peripheral ectoglic layer throughout telencephalon — thinnest in anterior wall. Formation of cinerea above and anterior to origin of olfactory nerve. Distinct though low paraphysis. Velum transversum 0.65 mm. in length at median line. Anterior wall twice as thick as posterior. Walls separated by layer of vascular mesenchyma. Distinct postvelar arch, with walls nearly in contact. Pinealis nearly 0.3 mm. long, extending backward over roof of diencephalon. Expanded distally. Small anterior commissure. Posterior commissure much larger. Ganglion habenulae differentiated. Differentiation of cinerea in ventral zone of mesencephalon. Tractus habenulo-peduncularis differentiated? A distinct bundle of fibers (tractus olfactorius habenularis?) pass from superior commissure ventrally and posteriorly half way to the optic chiasma. Fasciculus longitudinalis posterior can be traced throughout greater part of medulla. Tractus ascendens trigemini extends forward 200 μ anterior to origin of nerve. Tractus descendens can be traced posteriorly to origin of facial nerve. — Trochlearis present; extends downward beyond base of mesencephalon. Divisions of facial-acoustic ganglion only connected at origin of ganglion. Lateral line ramus of vagus extends posteriorly almost to caudal fin.	Walls of recessus infundibuli and recessus mammillaris separated by a deep external groove. Recessus infundibuli expanded laterally, the middle three-fifths of its cavity connecting with ventricle. Anterior part of hypophysis closed off, in the main, from mouth, thus forming a shallow sac which extends forward nearly to chiasma swelling. Posterior part of hypophysis as in preceding stage (No. 27). Distal end expanded laterally.
29	Telencephalon much expanded laterally. Lateral walls at level of origin of olfactory nerve 0.3 mm. thick. Choroid plexus indicated by two distinct but small folds — a few mesenchymal cells between walls of folds. Cinereal layer throughout walls of telencephalon. Pinealis 0.5 mm in length (by sections). Lumen of stalk occluded at base for 50 μ (by sections). Cerebellar anlagen much thickened on either side of median line with formation of cinerea. Lobus lineae lateralis forms a distinct projection of the inner wall of hind brain; bounded ventrally by a shallow groove. A very slight longitudinal groove separates the fasciculus longitudinalis medialis and lobus visceralis. Differentiation of reticularis throughout medulla. Many fibers in anterior part.	Hypophysis connected with mouth by narrow stalk, 250 μ in length (by sections) and 50 μ in diameter. Stalk contains minute lumen. Dorsal end of hypophysis greatly expanded, and divided into a median and two lateral sacculations — the median sacculation in contact with recessus infundibuli.
30	Beginning of lateral ventricles as very shallow broad diverticula from the ventral part of fore-brain vesicle. Lateral walls of telencephalon almost 0.5 mm. thick; ependymal layer occupies inner half of wall. Recessus neuroporicus a narrow slit, the walls of which are in contact ventrally. A narrow band of longitudinally directed fibers lies on either side of the choroid plexus in the upper part of the posterior wall of telencephalon. Lateral plexus in cross section twice as high as broad, each containing a single blood vessel. Paraphysis appears externally as a distinct fold in dorsal half of diencephalon. Velum transversum 0.8 mm. long at median line. Anterior wall three times as thick as posterior. Anterior and superior commissures as in preceding stages (No. 28, 29). Pinealis 0.7 mm. in length. Expanded distally; no lumen in proximal portion of stalk. Wall of mesencephalon thickened ventrally. Slight differentiation of cinerea in ventral zone, into outer and inner layers. Myelencephalon expanded anteriorly, walls lying almost in coronal plane. — Short palatine ramus of glossopharyngeal nerve, and pharyngeal rami of vagus. Intestinal ramus of vagus extends posteriorly to stomach.	Transverse diameter of sacculus (recessus) infundibuli 0.8 mm. Median half connected with brain. Ridge between recessus mammillaris and sacculus infundibuli much reduced in height. Hypophysis connected with oral epithelium by a stalk 60 μ in diameter, in which a lumen is barely visible. Slight lateral constriction between anterior and posterior lobes. Distal end of posterior lobe sacculated, as described for preceding embryo (No. 29).
31	Telencephalon extends forward almost to anterior border of mid-brain. Lateral wall 0.5 mm. thick ventrally. Cinerea separated laterally into inner and outer layers. Ependymal layer occupies inner third of wall. Lateral plexes extend 0.3 mm. into ventricle; free edges expanded but not convoluted. Pinealis and velum transversum each approximately 1 mm. in length at median line. Paraphysis extends forward a little over roof of telencephalon. Ventral half of walls of mesencephalon greatly thickened. Deep broad median fissure. Cinerea in ventral zone divided into an inner dense, and an outer lighter zone. Dorsal longitudinal fasciculi clearly differentiated in posterior part of mesencephalon, lying on either side of median groove. Interpeduncular ganglion differentiated in outer zone of cinerea. Beginning of formation of valvula of cerebellum. Longitudinal grooves in floor of medulla deeper and more distinct than before. Lobus lineae lateralis in most prominent part almost semicircular in cross section.	Ridge between infundibular and mamillary recesses obliterated. Distinct peripheral band of ectoglia in tuberculum posterius. Stalk of hypophysis 30 μ in diameter — lumen obliterated.
32	Telencephalon much flattened dorso-ventrally; extends forward as far as anterior wall of mesencephalon. Lateral walls much thickened (nearly 0.5 mm. in section) ventrally. Ependymal layer occupies approximately inner fourth of wall. Cinerea dividing into an inner and outer layer. Recessus neuroporicus a deep pit, directed a little dorsally and extending half through the brain wall. Choroid plexus elongated and convoluted; expanded distally, secondary folds arising from primary one. Paraphysis expanded distally, extending forward on roof of telencephalon. Velum transversum 1.0 mm. in length at median line — its free edge much thickened. Pinealis nearly 1 mm. in length, 150 μ in diameter distally. Stalk small, with lumen occluded at proximal end. Ventral zone of mesencephalon much thickened. Cinerea divided into inner and outer layers.	Infundibulum as in preceding stage (No. 31). Marked lateral constriction between anterior and posterior lobes of hypophysis. Hypophysis stalk a slender, twisted column of cells, 0.2 mm. in length, containing no lumen.

Spinal Cord, Spinal Nerves, Sympathetic	Eye	Nose	No.
Cord in trunk region ovoid in cross section — broadest ventrally. Vertical diameter from 0.25 to 0.30 mm. Transverse diameter five-sixths of vertical. Cord ends posteriorly by tapering to a point. A distinct lateral peripheral band of ectoglia which is broadest ventrally. Differentiation of nuclear zone as in preceding stage (No. 26). Spinal nerves extend to middle of pectoral fin fold, and to dorsal edge of pelvic fin fold. In cardiac region, dorsal rami extend nearly to dorsal edges of somites.	Greatest breadth of lens 0.38 mm., greatest thickness 0.25 mm. Lateral surface moderately, mesial surface barely convex. Mesial wall 150 μ, lateral wall 30 μ thick. Nuclei gathered in outer two-thirds of mesial wall. Less lentic cavity than in preceding embryo. Optic cup 0.75 mm. in diameter. Pars coeca bent centrally for 15 μ. Thickness of walls as in preceding stage (No. 26). A few division figures in outer angle of cup.	Little change from preceding stage (No. 26).	27
Cord throughout trunk and cardiac region almost circular in cross section — about 0.30 mm. in diameter. Ectoglia layer from 20 to 40 μ in thickness in trunk region. Oval bundle differentiated. Slight differentiation of lateral longitudinal fasciculus, and division of cinerea into dorsal and ventral columns in cardiac region. A very narrow ventral commissure in anterior trunk region. Many giant cells in cardiac region. Sympathetic ganglia, masses of darkly staining cells lying on dorsal surface of cardinal veins, and connected with spinal nerve trunks by short ganglionic cords.	Breadth of lens 0.92 mm., thickness 0.66 mm. Curvature of lateral surface somewhat more than hemispherical. Mesial surface almost flat. Lentic cavity nearly obliterated. Mesial wall forty times as thick as lateral. Lentic fibers decidedly converged. Greatest diameter of optic cup 1.4 mm. Thickness of retinal wall 150 μ, of chorioid wall 15 μ. Optic stalk 150 μ in diameter. Optic nerve fibers in distal part of stalk, anterior to chorioid cleft. Hyaloid artery and mesenchyma project well into optic cup.	Nasal pit shallow caudally and mesially. Invaginated at cranial end forming a pouch 200 μ in length (by sections). End of pouch expanded mesially and laterally — lateral enlargement is slightly the larger and extends farther anteriorly.	28
Transverse diameter of cord from 0.4 mm. to 0.5 mm. In pharyngeal and cardiac regions, cord almost circular in cross section. In remainder of trunk, broadly oval, with vertical diameter approximately three-fourths of transverse. In anterior part of tail, transverse and vertical diameters about equal. Canal twice as broad ventrally as dorsally in anterior trunk region. Division of cinerea into dorso-lateral and ventral columns. Lateral longitudinal fasciculus a distinct oval bundle throughout trunk region. Narrow ventral commissure throughout trunk region.	Lateral surface of lens decidedly rounded; mesial almost flat. Lateral and mesial surfaces join almost at right angles. Breadth of lens 1.4 mm., thickness 1.1 mm. Lentic cavity obliterated. Retinal layer of optic cup twelve times as thick as chorioid. A little mesenchyma between lower border of the pars coeca and skin. Optic stalk contains many fibers posteriorly.	Nasal sacs 240 μ in length (by sections). Division into lateral and mesial chambers has proceeded much farther. Mesial chamber much the larger, extending twice as far anteriorly (144 μ, by sections) as lateral. Two sets of Schneiderian folds, one in mesial chamber (three folds), one in lateral chamber (seven folds). Diameter of largest fold at base 45 μ, height 60 μ. Both epithelium and mesenchyma involved in folds.	29
Greatest transverse diameter of cord in trunk region, 0.4 mm. Vertical diameter four-fifths of transverse. Vertical diameter of canal approximately five times transverse. Canal slightly expanded at dorsal and ventral ends, and in the exact middle. Roof plate about half the diameter of floor-plate. Twenty-five (?) giant cells in cord, anterior to level of duodenum — none behind this region. Oval bundle and ventral commissure more definite than in preceding stage. Dorsal ganglionic commissure, connecting vagus, spino-occipital ganglia and first spinal ganglion, has disappeared.	Lateral surface of lens fully rounded, posterior curvature flatly rounded. Breadth of lens 1.4 mm., thickness 0.9 mm. Retinal layer of cup 215 μ, chorioid layer 15 μ thick. Differentiation between pars coeca and pars optica a little more marked than in preceding stage (No. 29). Pars coeca 230 μ in length, slightly folded on mesial surface. A trace of pigment in outer layer. Considerable mesenchyma between ventral border of pars coeca and skin. Cavity of optic stalk still present in anterior portion, obliterated posteriorly by optic fibers. Vascular mesenchyma enters by chorioid fissure, extending into optic cup as far as ventral surface of lens.	Four or five Schneiderian folds in median series, twelve or thirteen in lateral. Height of largest fold 105 μ, width 30 μ. Anlagen of nasal valves appear as slight thickenings of edges of nasal pit.	30
Transverse diameter of cord in anterior trunk region 0.5 mm. Vertical diameter four-fifths of transverse. Lateral longitudinal fasciculus sharply marked off — about 40 μ in diameter in cross section. Many glia cells in ectoglia of ventral funiculus.	Mesial surface of lens a little more rounded than in preceding stage. Breadth 1.7 mm., thickness 1.4 mm. Pars coeca longer, slender, but no more corrugated than in preceding stage (No. 30). Pigment extends from distal tip of pars coeca a little past point where iris process goes over into retina proper. Optic stalk obliterated by fibers except for 20 μ anteriorly. A thick band of mesenchyma between base of pars coeca and skin.	Eleven Schneiderian folds in mesial series, nineteen in lateral series. Bases of valves more distinctly marked off from pit wall than in preceding stage (No. 30). Mesial flap of nasal valve slightly overlaps lateral.	31
Cord in cardiac region broader ventrally than dorsally. 0.6 mm. to 0.7 mm. in transverse diameter — vertical diameter about four-fifths of transverse. In trunk region, cord 0.4 to 0.5 mm. diameter — vertical diameter about two-thirds of transverse. Beginning of dorsal closure of canal in cardiac region. Many glia cells in ventral funiculus. In cardiac region, a slight separation of dorsal column of cinerea layer into dorsal and lateral columns. Ventral white commissure nearly 40 μ in thickness. Numerous dorsal giant cells in cardiac region.	—	Mesial chamber lies almost entirely anterior to the lateral. Little if any increase in number of Schneiderian folds. Largest fold (lateral series) 60 μ wide and 225 μ high. Nasal flaps slightly constricted at their bases; mesial flap overlaps lateral.	32

No.	Ear	Integument, Lateral Line	Mouth	Archenteron
27	Vertical diameter of otocyst about three-fifths of length. Middle third of floor expanded, forming a broad shallow pouch (sacculus?). A shallow vertical groove on mesial surface of otocyst, midway between anterior and posterior ends.	Epithelium of lower half of lateral surfaces, and ventral surface of trunk, composed of an inner layer of cuboidal, and an outer layer of exceedingly squamous cells. In head region, ventral to optic vesicles, two layers of cuboidal cells, — along ventral median outer layer high columnar. Dorsal to supra orbital placode, a single layer of squamous cells. Lateral line placode extends posteriorly to pectoral fin.	Mouth opening as in preceding stage. Frontal process broader, projecting a little more from the head than in preceding stage (No. 26).	—
28	Sacculus a distinct thick-walled pouch from lateral side of posterior end of otocyst: Posterior end of lateral canal-pocket lies immediately above sacculus; marked off from utriculus above by a distinct groove; projects a little ventrally and posteriorly. Posterior canal-pocket a distinct pouch arising from the mesial surface of the otocyst, posterior to ductus endolymphaticus; and projecting backward 120 μ beyond posterior edge of lateral pocket. Ductus endolymphaticus arises from dorsal third of mesial surface of otocyst, midway between anterior and posterior ends. Extends dorsally to roof of hind-brain, then turning at right angles extends posteriorly 200 μ before fusing with epithelium of skin.	Epithelium composed of an inner layer of cuboidal or columnar cells, and an outer layer of squamous cells. A definite basement membrane present. Outer layer of cells markedly thickened (columnar) on ventral surface of head, mesial and anterior to olfactory pits, forming a rostral plate, thelateral and posterior boundaries of which are distinguishable in external view. Supraorbital placode and lower part of postorbital placode visible in external view. Lateral placode extends posteriorly to level of cloaca. (See note under remarks.)	Mouth opening broadly oval in outline, broader than long. Maxillary and mandibular processes meet at an angle of nearly 100°. Anterior ends of maxillary processes much enlarged — separated by a shallow cleft approximately one-fifth as broad as mouth opening. Rounded frontal process projects into lower half of cleft. A shallow median groove separates bases of mandibular processes.	—
29	Sacculus flask-shaped in cross section, projecting posteriorly as a blind sac. Anteriorly, connected with utriculus. Lined with very high ciliated (?) epithelium. Antero-lateral and posterior canal-pockets enlarged distally.	Epithelium much as in preceding stage (No. 28). Mesenchyma a little condensed below it. Outer cells of rostral plate about twice as high as those of inner layer. Viewed externally, supraorbital canal arises over middle of eye and is continuous ventrally with ethmoid canal. Ethmoid canal turns sharply mesially and joins angular canal below nasal pits. Praeoral canals continuous with angular and ethmoid; do not meet at median line. Angular canals turned mesially at posterior ends, extending inward a little beyond angle of mouth. — Postorbital canal does not extend dorsally beyond lower edge of eye. Lateral placode extends to middle of caudal fin.	Mouth opening lenticular in outline, nearly three times as broad as long. Anterior ends of maxillary processes not prominent — separated at median line only by a faint groove. Frontal process overhangs maxillary processes at median line. No line of separation between bases of mandibular processes.	—
30	Anterior four-fifths of sacculus connected with utriculus by a stalk which is a little constricted transversely. Ventral half of lateral canal-pocket separated from utriculus. Posterior end projects backward as a blind pouch. Posterior half of posterior canal-pocket separated from utriculus — curved a little laterally. Anterior canal-pocket not as distinct as posterior and lateral. Horizontal limb of ductus endolymphaticus 250 μ in length (by sections).	Epithelium much as in preceding stage (No. 29) — outer layer of cells more squamous. Cells of outer layer of rostral plate apparently degenerating. In sections, ampullae appear in rostral plate as clusters of cells arranged like those of taste-buds. Outlines of rostral plate, as viewed externally, indistinct. Viewed externally, supraorbital canal extends posteriorly to above last gill slit. Postorbital canal joins supraorbital posterior to eye.	Mouth opening three times as broad as long. Maxillary processes separated by a shallow median groove. Labial pockets appear as slight depressions lying lateral to angles of mouth.	—
31	Anterior canal separated from pocket dorsally, lies mainly dorsal to utriculus. Middle portion of horizontal canal completely cut off from pocket. Connections of anterior and posterior portions much constricted. Posterior canal cut off from pocket for a considerable distance. Distinct expansion of antero-lateral ampulla. Canal between sacculus and utriculus longer but not narrower than before. Sacculus smaller in comparison with utriculus than in preceding stage (No. 30).	Integument composed of an inner layer of cuboidal or columnar cells, and one or two outer layers of squamous or, occasionally, cuboidal cells. Mesenchyma condensed below epithelium. In places, mesenchymal cells epithelioid in arrangement. Occipital canal established. Anterior limbs of median canal system, established, — extend ventrally to a point somewhat in front of nasal pits; no median part yet established. Ampullae appear externally as minute whitish thickenings of epidermis. Mandibular, postorbital, anterior and posterior infraorbital and orbital groups established. In section, ampullae appear as shallow depressions, which extend through 3—4 sections of 20 μ and are lined with closely packed elongated cells of inner layer of epithelium.	Lateral angles of mouth bounded by narrow elevated jaw-ridges. Upper jaw-ridge projects a little over lower. Well defined labial pockets lateral to jaw-ridges.	—
32	Semicircular canals as in preceding embryo, except for expansion of ampulla. A slight transverse construction of sacculus, dividing it into sacculus proper and lagena. Ductus endolymphaticus a little expanded just ventral to horizontal limb. Horizontal limb extends 0.5 mm. posteriorly, opens to surface of body.	Epithelium as in preceding stage (No. 31). Epicranial and hyoid groups of ampullae visible in external view.	Jaw-ridges narrower and more projecting than in preceding stage (No. 31). Deep labial pockets, which are invaginated anteriorly.	—

Pharynx, Thyreoid, Thymus, Suprapericardial Body	Digestive Tube	Liver, Pancreas, Spleen	No.
Five anterior gill slits open, sixth slit still closed by a thin plate of epithelium. Short gill filaments from second, third, and fourth slits. Thyreoid 200 μ in length (by sections). Anterior half attached to floor of pharynx by a constricted neck.	Lumen of posterior two-fifths of oesophagus occluded. Walls actually fused for about ten sections of 10 μ only. A few cellular strands stretch across the lumen for 250 μ anterior to this region. Anterior three-fifths of oesophagus flattened dorso-ventrally; where most flattened, ventral diameter about one-third of transverse. Stomach about twice diameter of closed oesophagus, about 0.6 mm. in length (by sections). A slight constriction between stomach and duodenum. Duodenum curved a little to the left and downward, at an angle of 60°. Vitelline duct, at its upper end, of same diameter as gut. Ten turns of spiral valve. Lumen of gut much constricted just anterior to cloaca. Digitiform gland a solid bud on dorsal surface of gut, posterior to last turn of spiral valve. Cloaca dilated — floor in contact with ectoderm for 0.6 mm.	Gall bladder 220 μ in length (by sections), expanded at distal end. Connected with ductus choledochus by short broad cystic duct, which arises from anterior fourth of its dorsal wall. Ductus choledochus arises from an expanded chamber which receives two lateral and one anterior hepatic duct, and cystic duct. Joins intestine on ventral surface, 140 μ anterior to opening of vitelline duct. Pancreas connected by broad neck with intestine, near the middle of left side, a short distance behind opening of vitelline duct. A distinct posterior diverticulum of this neck at juncture with gut. Spleen a slight thickening on left side of mesentery, just posterior to stomach.	27
First (spiracular) cleft one-half as long as others. Lies at an angle of 45° to longitudinal axis of body. Long gill filaments from second, third, fourth, and fifth slits. Four short filaments spring from ventral part of anterior wall of first slit. Thyreoid detached completely from floor of pharynx, much mesenchyma between the two structures. Outer cells of thyreoid epithelioid in arrangement, surrounded by a definite basement membrane. Suprapericardial body represented by small patch of thickened epithelium of floor of pharynx on left side of median line at level of sixth gill pouch.	Vertical diameter of anterior end of oesophagus one-seventh of transverse. Posterior half of oesophagus solid. Stomach about 0.7 mm. in length (by sections), middle third dilated. Duodenum curved a little dorsally at anterior end, directed ventrally at an angle of 45° posteriorly. Vitelline duct enters gut on right side at base of duodenal curve. Twelve and one-half turns of spiral valve. Lumen of intestine much constricted just anterior to cloaca; one-seventh diameter of gut at this point. Digitiform gland 150 μ in length (by sections), lies entirely dorsal to intestine attached to intestine along almost its entire length. Cloaca 0.4 mm. in length; its floor in contact, but not fused, with skin epithelium. Mesenterial fenestra, lying anterior to digitiform gland, 0.5 mm. in length.	Lateral lobes of liver extend backward to between first and second turns of spiral valve. Hepatic tubules from 40 to 50 μ in diameter. Eight to ten cells in cross section. Lumen about one-sixth diameter of tubule. Gall bladder elongated, expanded at ventral end. Cystic duct elongated as compared with preceding stage; its long axis in vertical plane of body. Ductus choledochus not dilated at distal extremity. Arises from union of cystic and three hepatic ducts. In anterior half of course is arched dorsally. Joins intestine on left side, just behind opening of vitelline duct. — Body of pancreas lies above and to left of first turn of spiral valve. Made up of short irregular tubules opening into dilated distal extremity of pancreatic duct. Pancreatic duct joins intestine on left side of ventral surface, 120 μ (by sections) posterior to entrance of ductus choledochus. A considerable mass of pancreatic tissue ventral and to left side of duct at its juncture with intestine. Spleen a projecting mass of thickened mesenchyma from left side of mesogastrium and mesentery, 370 μ in length (by sections).	28
Long gill filaments from all clefts. Thyreoid almost 0.5 mm. in length. Oval in cross section. Contains numerous small irregular cavities. Suprapericardial body a small deep thick-walled pit in floor of pharynx on left side near the median line at upper end of the sixth gill pouch. Extends through three sections of 12 μ.	Vertical diameter of oesophagus one-sixth of transverse. Lumen of posterior end occluded for 0.25 mm. (by sections). Longitudinal furrows in epithelium at lateral angles of anterior part of oesophagus. Mesenchyma about epithelium much condensed, outer cells having elongated form of myoblasts. Stomach oval in cross section, surrounded by dense stroma of thickened mesenchyma. Fundus projects as a blind pouch 100 μ posterior to pyloric opening. Duodenum joins stomach almost at right angles, posterior duodenal curve slightly indicated. Thirteen turns of spiral valve in dissected specimen of same size. Gut slightly constricted posterior to last turn of spiral valve. Lumen occluded in this region for 200 μ (by sections). In occluded region, external surface of epithelium is indented by three to six grooves, giving the intestine a lobulated appearance in cross section. Digitiform gland 0.5 mm. in length; lumen irregular, opens into gut through a low papilla just posterior to solid region. Cloaca triangular in cross section, epithelium of its ventral surface fused with that of skin for a few sections. Dorsal wall of posterior part of cloaca indented by the swelling of fused portion of the Wolffian ducts.	Liver approximately the same size as in preceding stage (No. 28). Tubules similar to those in preceding stage. Ductus choledochus joins intestine on ventral surface, just posterior to entrance of vitelline duct. Pancreatic duct joins intestine on ventral surface, 0.3 mm. (by sections) posterior to ductus choledochus. Spleen 0.5 mm. in length (by sections), extends posteriorly nearly to level of second turn of spiral valve; broadest posteriorly. Epithelium higher than that of mesentery. Mesenchyma of spleen compact and vascular.	29
Spiracular slit broadly lenticular in outline, one-fourth length of hyoid slit. Epithelium on lateral side of dorsal tips of 2nd, 3rd, 4th, and 5th pouches thickened (anlagen of thymus). Suprapericardial body expanded at distal end, constricted at connection with pharyngeal epithelium.	Lumen of oesophagus occluded at posterior end for 240 μ (by sections). Longitudinal grooves in epithelium more numerous than in preceding stage. Duodenal curve flatly S-shaped. Vitelline duct in upper part about diameter of duodenum. Expanded to form an irregular sack before joining gut. Its opening into gut 140 μ in length (by sections). Fourteen turns of spiral valve. Lumen of gut occluded for 100 μ (by sections), a little posterior to last turn of spiral valve. Grooves in surface of gut in this region extend through its outer third. In a dissected specimen of 28.0 mm., digitiform gland 1.2 mm. in length, its inner surface sacculated. Opens into gut by a constricted and convoluted duct which arises a little in front of posterior end of gland.	Lateral lobes of liver approximately 2.5 mm. in length, extending backward to level of third turn of spiral valve. Average diameter of hepatic tubules 75 μ. Lumen one-seventh diameter of tubule: bounded by six to eight cells in cross section. Ductus choledochus joins intestine on ventral surface, 1.0 mm. (by sections) posterior to entrance of vitelline duct. Pancreatic duct joins intestine on left side 0.2 mm. posterior to entrance of ductus choledochus.	30
Gill filaments longer (over 6.0 mm.). Epithelium of thymus anlagen increased in thickness. Thyreoid nearly 1.0 mm. in length. Anterior and posterior thirds of thyreoid circular in cross section, with no lumen. Middle third a flattened plate 0.45 mm. in width and 0.08 mm. thick, containing an irregular central lumen. Distal end of suprapericardial body expanded and directed posteriorly. Only a very minute lumen in stalk.	Furrows in epithelium of oesophagus as in preceding stage (No. 30). Three broad longitudinal folds, involving both epithelium and mesenchyma in dorsal wall of oesophagus. Lumen of oesophagus occluded for 0.3 mm. (by sections). Fourteen turns of spiral valve. Intestine 1.8 mm. in diameter in broadest (middle) part, in a dissected specimen of 34.0 mm., digitiform gland 2.0 mm. in length.	Lateral lobes of liver 7.5 mm. in length in dissected specimen of 34.0 mm. Extend backward to middle of body cavity. Lumina approximately one-tenth diameter of hepatic tubules. Ductus choledochus joins intestine on right side, about 0.6 mm (by sections) posterior to entrance of vitelline duct. Tubules of pancreas broadly separated by septa of mesenchyma. Pancreas shows adult divisions of head, isthmus, and body. Pancreatic duct joins intestine on ventral surface at base of first turn of spiral valve, 0.25 mm. (by sections) posterior to entrance of ductus choledochus. Spleen 1.5 mm. in length (by sections). Posteriorly attached to mesentery only by ventral border.	31
Gill filaments and thymus anlagen as in preceding stage. Posterior half of thyreoid a flattened plate — anteriorly lumen much expanded. Distal end of suprapericardial body expanded, forming a thin-walled cyst 120 μ in length. Stalk twisted, with an irregular lumen which does not communicate with pharyngeal cavity nor with cavity of distal cyst.	Folds in dorsal wall of oesophagus extend posteriorly to occluded portion. About six smaller longitudinal folds in ventral wall. Solid portion of oesophagus 0.3 mm. in length (by sections). Mesenchyma condensed immediately below epithelium. Muscularis a definite band of elongated cells as wide as epithelial lining of gut in this region. Lumen of intestine occluded for 0.3 mm. (by section) posterior to last turn of spiral valve. Grooves in gut in this region deeper and wider than in preceding stage. Digitiform gland 2.5 mm. in length.	Lateral lobes of liver 12.0 mm. in length in a dissected specimen of 37.0 mm; extend backwards through anterior three-fifths of body cavity. Generally six or seven cells in cross section of hepatic tubule. Lumen from one-twelfth to one-fifteenth diameter of tubule. Gall bladder 0.7 mm. in length (by sections), 0.2 mm. in diameter. Ductus choledochus 0.075 mm. in diameter, joined by four hepatic ducts in upper part of course. Joins intestine on the upper part of its right side, 0.6 mm. (by sections) posterior to entrance of vitelline duct. Epithelium of both gall bladder and ductus choledochus surrounded by dense layer of flattened mesenchymal cells. Lower part of pancreatic duct lies in groove on floor of intestine. Joins with intestine on right side of ventral surface, 0.5 mm. posterior to entrance of ductus choledochus.	32

No.	Urogenital System	Heart, Pericardium, Blood Vessels
27	Wolffian duct opens into body cavity at level of anterior end of pancreas, is preceded by long shallow groove. Extreme posterior end solid, fused with lateral wall of posterior part of cloaca. Forty-one pairs of mesonephric tubules — the first four rudimentary. Posterior tubules extend outward and upward over dorsal surface of Wolffian duct. Expanded at their distal ends and in contact, but not fused, with dorsal wall of duct. Interrenal organ as in preceding stage (No. 26). 209 germ cells in genital region (WOODS).	Walls of both atrium and ventricle much thicker than in preceding stage. Atrium lies mainly over much expanded bulbus. Anlagen of valves of bulbus, three mesenchymal thickenings of endothelial lining at level of tip of dorsal extension of pericardium. Atrio-ventricular valves represented by slight thickening of endothelial wall of atrio-ventricular canal. Anterior part of pericardial cavity, which receives stalks of premandibular and hyoid cavities, is connected with cavity proper only by a pair of solid mesothelial cords. — Six complete aortic arches in sagittal series (H.E.C. 203). Sixth arch not complete in transverse series. Formation of efferent vessels from anterior five arches (H.E.C. 204). Ventral aorta bifurcates at origin of third arch. First arch much reduced in caliber at its base. — Vena capitis lateralis nearly equal in caliber to V. cap. mesialis. Extends forward beyond otocyst, and communicates with V. cap. mesialis by branches passing between branchial rami of vagus, between vagus and glossopharyngeal, between glossopharyngeal and otocyst, and, finally, in front of otocyst. Lateral veins open into common cardinals just above sinus venosus — can be traced backward for a few sections only.
28	Wolffian duct opens into coelom anteriorly in mid stomach region. Two distinct folds in somatic mesoderm below this opening. Ducts fused together, and with dorsal wall of cloaca at posterior ends. Thirty-eight mesonephric tubules, anterior two rudimentary. All tubules, except anterior two, connected with Wolffian duct. All except anterior two tubules dilated before joining duct to form Malpighian corpuscle — no glomeruli. Anterior part of interrenal organ made up of anastomosing cords of cells among sinusoids of cardinal veins; posteriorly, organ as in preceding stages (No. 27). Genital ridges extend from level of first to level of sixth turn of spiral valve. In largest part 75 μ high, 60 μ broad at base.	Walls of ventricle and bulbus considerably thickened. Many muscle fibrils in all heart chambers — not cross-striated. Dorsal surface of bulbus is fused with floor of atrium anteriorly. Valves of bulbus meet centrally, their edges are a little thickened. Atrio-ventricular valves thickened at their free edges. — Lumen of first aortic arch completely occluded at its base. Connections of afferent portions of third, fourth, and fifth arches reduced to impervious cords. Dorsal aortae between second and third arches reduced to minute vessels, about one-fourth caliber of aortae, posterior and anterior to this segment. Vertebral, lieno-gastric, and posterior mesenteric arteries developed. — Anterior cardinal vein extends forward to glossopharyngeal nerve. Connected with vena capitis medialis by two vessels — one immediately anterior to common cardinal and one at level of first spino-occipital ganglion. Vena capitis medialis united with anterior cardinal at level of second spino-occipital ganglion. Extends forward to trigeminal ganglion, where it unites with V. cap. lateralis. V. cap. lateralis much larger than V. cap. medialis. Lateral vein opens into sinus venosus just below common cardinal. Extends posteriorly to pelvic fin. Receives vein from pectoral fin. Jugular vein opens into sinus venosus with lateral vein — extends forward to thyreoid. Vertebrals dilated over dorsal surface of Wolffian body. A small vessel (lateral mesonephric vein) extends along the base of the lateral surface of the Wolffian body. It communicates with posterior cardinal in front of first Wolffian tubule, and with caudal vein posteriorly.
29	Thirty-five mesonephric tubules on left side, first two and last being rudimentary and not connected with Wolffian duct. Glomeruli present on all except rudimentary tubules, rudimentary on third and fourth tubules. Anterior nephrotomes are set at an oblique angle to longitudinal axis of body. The posterior ones lie transversely. The hindmost tubules show development of accessory ureters, "Nebenharnleitern". Müllerian ducts open anteriorly into body cavity on sides of septum transversum about one half way ventrally, much reduced in size posteriorly, join Wolffian duct between 15th and 16th tubules. Posterior ends of Wolffian ducts turn sharply downward and fuse together over cloaca. Interrenal organ made up of a loose meshed syncytium. Genital folds 60 μ high, 75 μ broad.	Walls of ventricle and bulbus much thickened with numerous sinusoids, walls of atrium as before. Numerous muscle fibrils, none of which appear to be cross-striated. Pericardial cavity completely cut off from the coelom ventrally by the septum transversum. Dorsal openings into the coelom are still large. Peritoneal-pericardial canal as broad as oesophagus above it, 220 μ in length (by sections). — Afferent and efferent branchial arches completely separated. Occluded processes of afferent vessels extend dorsally, but do not connect with efferent vessels. — Vena capitis lateralis forms main anterior continuation of anterior cardinal. V. cap. mesialis represented by a few small chambers which communicate with V. cap. lateralis. Orbital sinus as in preceding embryo. Posterior cardinal veins arise by bifurcation of caudal at level of 27th mesonephric tubule. Lateral mesonephric veins larger than in preceding embryo. Open into ventral surface of caudal vein, posterior to the 35th (last) mesonephric tubule. Do not communicate with cardinals directly in Wolffian body, but are connected by large vessels with the enlarged bases of the segmental veins. Anterior to 1st mesonephric tubule, lateral mesonephric veins open directly into posterior cardinals. — Corpuscles broadly oval to round, flatly convex, about 20 μ in diameter. Nucleus stains darkly, but is not homogeneous.
30	Thirty-seven mesonephric tubules, first four and last two rudimentary. Müllerian ducts open anteriorly into body cavity on wall of septum transversum, near median line and ventral border. Müllerian duct separate from Wolffian duct anterior to the seventeenth mesonephric tubule. Wolffian ducts communicate posteriorly for 30 μ. Genital folds extend from region of closed oesophagus to the twenty-sixth mesonephric tubule, i. e., just posterior to spiral valve; longest in region of stomach. 496 germ cells in genital ridge (WOODS). Interrenal organ as in preceding stage.	Walls of atrium a little thicker than in preceding stage (No. 29). Fibrils in all chambers of heart cross-striated. Pericardial-peritoneal canal 0.25 mm. in length (by sections), connecting plate forming posteriorly. — Segmental veins dilated over dorsal surface of Wolffian body — from these dilatations vessels pass to posterior cardinal and lateral mesonephric veins. In some places, dilatations of two or three successive segmental veins, connected by narrow longitudinal channels. Lateral mesonephric veins open anteriorly into posterior cardinals in front of first mesonephric tubule; open into caudal vein by several channels posteriorly.
31	Thirty-six well developed mesonephric tubules, posterior ones open into Wolffian duct by short accessory ureters, "Nebenharnleitern". Müllerian ducts meet at ostium, which is located in median line of septum transversum. Müllerian and Wolffian ducts join between thirtieth and thirty-first mesonephric tubules. The fused posterior ends of Wolffian ducts form a decided swelling on dorsal wall of cloaca, but do not open into it. 710 germ cells in genital ridge (WOODS).	Ventricle much enlarged; muscle arranged in distinct trabeculae. Peritoneal-pericardial canal approximately 0.3 mm. in length (by sections), constricted posteriorly by connecting plate. — Continuous dorsal mesonephric vein, formed by fusion of dilated bases of segmental veins. Communicates with cardinals by main channels above glomeruli. Small sinusoids throughout Wolffian body, dorsal to glomeruli*). Lateral mesonephric vein anteriorly small and indistinct; posteriorly enlarged, receiving vessels from dorsal mesonephric, and broadly connected with caudal vein. — Corpuscles flatly biconvex, roundly oval in outline, 20—25 μ in diameter. Nucleus densely reticular.
32	—	Ventricle trabeculae much more compactly arranged, ventricle much larger. Peritoneal-pericardial canal approximately 0.5 mm. in length — opens on ventral surface of the anterior part of stomach. Very much reduced in calibre posteriorly by further fusion of connecting plate. — Dorsal mesonephric veins larger than in preceding stage — broadly connected with posterior cardinals by sinusoids. Lateral mesonephric veins small and indistinct anteriorly; enlarged posteriorly, and connected by broad channels with dorsal mesonephric veins. Broadly connected with caudal vein posteriorly. Cardinal sinus an irregular vascular chamber, lying above radix mesenterica; communicating by broad channels with posterior cardinals of either side; receives genital vein posteriorly.

*) The vessel to which the purely topographic term "dorsal mesonephric" vein has been applied, arises, as described, by a fusion of the bases of the segmental veins. It corresponds in position, however, to the posterior cardinal of mammals. The vessel which arises first in *Acanthias*, and which has been termed the posterior cardinal vein because of this origin, occupies the position of and probably corresponds with the subcardinal of mammals.

Extremities	Remarks	No.
Posterior and anterior dorsal fins approximately 0.25 mm. high. Median fold between dorsal fins almost obliterated. Posterior part of dorsal and ventral folds thickened to form caudal fin. Pectoral fin thickened at its base, approximately 2 mm. long. Muscle buds very much constricted at proximal ends. Distal ends expanded and bifid. Nearly all buds united by mesothelial processes. Pelvic fins represented by a very slight swelling of the somatopleure just anterior to cloaca; mesenchyma increased in amount and condensed; epithelium composed of two layers of cells.	Cleared and dissected specimens of same stage used in preparation of descriptions of heart, brain, digestive tract, and somites. — Mouth described from specimen of same stage, but not one of series. Fig. 22. Digestive tract and heart of dissected specimen of same stage. Literature: MINOT, C. S., 1901, Morphology of the pineal region. Amer. Journ. Anat., I (Series 224).	27
Anterior dorsal fin 1.6 mm. in length at base, nearly 0.5 mm. high; posterior edge rising more abruptly from back line than anterior. Posterior dorsal fin 1 mm. in length at base, 0.5 mm. high, in shape as anterior fin. Mesenchyma of dorsal fins condensed. Cells proliferating into the mass from dorsal myotomes of fin region? Median fin fold in caudal region 0.4 mm. high. Pectoral fin 2 mm. in length, 1.2 mm broad, gradually rounded anteriorly, sharply rounded posteriorly; turned a little ventrally posteriorly. Primary muscle buds almost completely divided into dorsal and ventral secondary buds, which extend to respective surfaces of fins. Primary buds completely separated from somites. Pectoral girdle represented by a slight condensation of mesenchyma in body wall on either side, below anterior part of pectoral fin. Pelvic fins 2 mm. in length at base, posteriorly fusing into low rounded ridge behind the cloaca; mesenchyma much condensed. Slight division of distal end of muscle buds into dorsal and ventral diverticula. Primary buds connected with somites by slender necks which are becoming mesenchymous.	Reconstructed. Fig. 16. General structure. Cleared and dissected specimens of same stage used in preparation of descriptions of heart, brain, digestive tract. — Mouth described from specimen of same stage, but not one of series. Fig. 23. Digestive tract and heart of dissected specimen of same stage. Literature: MINOT, C. S., 1901, Morphology of the pineal region. Loc. cit. (Series 228.) WOODS, F. A., 1902, Origin and migration of the germ cells in Acanthias. Amer. Journ. Anat., II.	28
Anterior dorsal fin 2 mm. long at base, 0.6 mm. high. Posterior fin 1.5 mm. long at base. Transverse diameter of fins about equal at base and distal edge. Caudal fin about 5 mm. long, 0.5 mm. high dorsally and ventrally. Median fin fold has entirely disappeared except between posterior dorsal and caudal fin. Pectoral fin extended outward at right angles to body, anterior edge roundly curved, posterior edge decidedly concave, about 2 mm. long at base. Proximal part of muscle buds becoming fibrous. Anlage of basipterygium a marked condensation of the mesenchyma at base of anterior fin. Continuous proximally with the condensation representing the pectoral girdle. Lateral anlagen of pectoral girdle are fused at median line anterior to yolk stalk. Extend dorsally to level of aorta. Dorsal extensions prolonged posteriorly. Pelvic fin 2.0 mm. long at base, 0.75 mm. broad; anterior edge rounded, posterior edge right-angled.	Cleared and dissected specimens of same stage used in preparation of descriptions of heart, brain, digestive tract.	29
Median fins much as in preceding stage (No. 29); caudal fin a little broader. Pectoral fin of about same dimensions as in preceding stage. Slight differentiation of basipterygium condensation into an anterior part (propterygium) and a posterior part (meso- and metapterygium). Distal portion widely expanded, but not divided as yet into radials. Distal ends of muscle buds undifferentiated. Pelvic fin 2.5 mm. in length at base. Basipterygium indicated by a very slight thickening of mesenchyma. Muscle buds on upper and lower surfaces of fin.	Cleared and dissected specimens of same stage used in preparation of descriptions of heart, brain, digestive tract. Fig. 24. Digestive tract and heart of dissected specimen of same stage.	30
Dorsal fins higher and more rounded than in preceding stage (No. 30). Posterior borders concave; base of each about 2 mm. in length. Caudal fin much expanded, point of greatest height on dorsal fold, posterior to that of ventral. Pectoral fin 2 mm. long at base, distal edge 3 mm. long, posterior edge directed sharply backward. Basale propterygii, mesopterygii, and metapterygii, outlined in thickened mesenchyma. Fin rays long radial thickenings of mesenchyma, — about nine on distal edge of mesopterygium and six on metapterygium. Pelvic girdle outlined in dense mesenchyma. Lateral halves fused beneath posterior end of pericardial cavity. Pelvic fin 2 mm. long at base. Primary basipterygium distinctly outlined, — rays from its free edge.	Cleared and dissected specimen of same stage used in preparation of descriptions of heart, brain, digestive tract, and somites. — Mouth described from specimen of same stage, but not one of series. — External appearance of lateral line system described from specimen of same stage, but not one of series. Fig. 25. Digestive tract and heart of dissected specimen of same stage. Literature: MINOT, C. S., 1901, Morphology of the pineal region. Loc. cit. (Series 362).	31
Spines of anterior and posterior dorsal fins represented by small blunt projections from base of anterior edge of fin. General shape of pectoral and pelvic fins unchanged from preceding stage (No. 31). Ventral portion of pectoral girdle and basipterygii precartilaginous. Fin rays much longer and more definitely outlined. Basipterygium of pelvic fin elongated, numerous elongated rays on distal edge.	Cleared and dissected specimen of same stage used in preparation of descriptions of heart, brain, digestive tract, and somites. — Mouth described from specimen of same stage, but not one of series. — External appearance of lateral line system described from specimen of same stage, but not one of series. Fig. 26. Digestive tract and heart of dissected specimen of same stage. Literature: LOCY, W. A., 1905, On a newly recognized nerve connected with the fore-brain of Selachians. Anat. Anz., XXVI (Series 353).	32

Reconstructions and Dissections.

List of Figures.

Explanation of Lettering of Figures.

A.

A. Archenteron
A.br.aff. Afferent branchial artery
A.br.eff. Efferent branchial artery
A.col. Coeliac artery
A.hyo.aff. Afferent hyoidean artery
A.hyo.eff. Efferent hyoidean artery
A.oph. Ophthalmic artery
A.proneph. Pronephric artery
A.seg. Segmental artery
A.vit. Vitelline artery
Ant.neur. Anterior neuropore
Ao.a. I, II, III, IV, V Aortic arches
Ao.dors. Dorsal aorta
Ao.vent. Ventral aorta
At. Atrium

B.

B.cor. Bulbus cordis

C.

C.ceph. Cephalic nerve crest
C.fa.ac. Facial-acoustic nerve crest
C.g-ph. Glossopharyngeal nerve crest

C.g-ph.-vag. Glossopharyngeal-vagus nerve crest
C.p. Cephalic plate
C.p.ant. Anterior canal pocket
C.p.lat. Lateral canal pocket
C.sp. Spinal nerve crest
C.thal. Thalamic nerve crest
C.trig. Trigeminal nerve crest
C.trig.-fac. Trigeminal-facial nerve crest
C.urtr. Urtrochlear nerve crest
Cb. Cerebellum
Cl. Cloaca
Cl.p. Cloacal plate
Cn.eth. Ethmoid canal
Cn.hyo. Hyoid canal
Cn.inf.orb. Infraorbital canal
Cn.inf.ros. Infrarostral canal
Cn.m. Median canal
Cn.pre-o. Pre-oral canal
Comm.d. Dorsal ganglionic commissure

D.

D.chol. Ductus choledochus
D.cyst. Cystic duct
D.endol. Ductus endolymphaticus
D.mes. Dorsal mesocardium
D.panc. Pancreatic duct
D.vit. Ductus vitellinus
Dig.gl. Digitiform gland
Duo. Duodenum

E.

Epi. Epiphysis

F.

F.g. Fore gut
F.r.-mes. Rhombo-mesencephalic fissure

G.

G.bl. Gall bladder
G.br.X Branchial ganglia of vagus nerve
G.cil. Ciliary ganglion
G.epib. Epibranchial ganglion
G.mes. Mesocephalic ganglion
G.r.bucc.VII Ganglion of buccal ramus of facial nerve
G.r.hyo.VII Ganglion of hyoid ramus of facial nerve
Gr.lat.X Ganglion of lateral ramus of vagus nerve
G.r.opt.sup.VII Ganglion of superficial ophthalmic ramus of facial nerve
G.sp.oc. Spinal-occipital ganglion
G.va.(I, II, III, IV) Branchial ganglia of vagus
Gl.c. Gill cleft
Gl.p.(I, II, III) Gill pouchs
Gl.s.(I, II, III) Gill slits

H.

H. Heart
Hyp. Hypophysis

I.

In.neur. Incisura neurenterica
Inf. Infundibulum

L.

L. Liver
L.a. Anterior liver pouch
L.g. Lateral groove of vitelline duct
L.l. Lateral liver pouch
L.m. Lateral mesoderm
L.p. Labial pocket
L.term. Lamina terminalis
Ls. Lens
Ls.p. Lentic pit

M.

M. Mesoderm
M.c. Medullary canal
M.f. Medullary fold
M.g. Medullary groove
M.pl. Medullary plate
M.r. Median ridge
Mes. Mesentery
Mes.f. Mesenterial fenestra
Mes.preo. Preoral mesoderm
Mes.t. Mesonephric tubule
Mesen. Mesencephalon
Mo. Mouth

N.

N.ab. Abducent nerve
N.ac. Acoustic nerve
N.fac.-ac. Facial-acoustic nerve
N.gl-ph. Glossopharyngeal nerve
N.oc. Oculo-motor nerve
N.olfact. Olfactory nerve
N.op. Optic nerve
N.p. Nasal pit

N.sp.-oc. Spinal-occipital nerve
N.term. Terminal nerve
N.tr. Trochlear nerve
N.trig. Trigeminal nerve
N.vag. Vagus nerve
Neur.c. Neurenteric canal
No. Notochord

O.

Oes. Oesophagus
Op.s. Optic stalk
Op.v. Optic vesicle
Or.pl. Oral plate
Oto. Otocyst
Oto.d. Depression in wall of hind-brain caused by otocyst

P.

Pa. Paraphysis
Panc. Pancreas
Panc.b. Body of pancreas
Panc.h. Head of pancreas
Pc. Pericardium cavity
Pc.w. Pericardium
Pelv.f. Pelvic fin
Ph. Pharynx
Post.d.f. Posterior dorsal fin
P.g. Preoral gut
P.mes. Preoral mesoderm
Pr.urt. Urtrochlear process — trigeminal crest
Proneph. Pronephric tubules

R.

R.bucc.VII Buccal ramus — facial nerve
R.dors.sp. Dorsal ramus — spinal nerve
R.hyo.VII Hyoid ramus — facial nerve
R.lat.X Lateral line ramus — vagus nerve
R.md.V Mandibular ramus — trigeminal nerve
R.mes. Radix mesenterica
R.mx.V Maxillary ramus — trigeminal nerve
R.oph.prof.V Deep ophthalmic ramus — trigeminal nerve
R.oph.prof.VII Deep ophthalmic ramus — facial nerve
R.oph.sup.V Superficial ophthalmic ramus — trigeminal nerve
R.oph.sup.VII Superficial ophthalmic ramus — facial nerve
R.p. Rostral plate
R.s-t.IX Supratemporal ramus — glossopharyngeal nerve
R.vis.X Visceral ramus — vagus nerve
Rec.postop. Recessus postopticus

S.

S.ceph. Cephalic sinus
S.v. Sinus venosus
S.trans. Septum transversum
Sac. Sacculus
Sn.r. Subnotochordal rod or hypochorda
So. Somite
So.ant. Anterior somite
So.hyo. Hyoid somite
So.mand. Mandibular somite
So.prem. Premandibular somite
Sp.c. Spinal cord
Sp.g. Spinal ganglion
Sp.v. Spiral valve
St. Stomach
St.br. Stalk, first branchial somite
St.mand. Stalk, mandibular somite
St.hyo. Stalk, hyoid somite
Symp. Sympathetic ganglion

T.

T.mes. Trunk mesoderm
Telen. Telencephalon
Th. Thyreoid

V.

V. Ventricle
V.cap.med. Vena capitis medialis
V.card.com. Common cardinal vein
V.jug. Jugular vein
V.lat. Lateral vein
V.subint. Subintestinal vein
V.vit.rec. Recurrent vitelline vein
V.vit.s. Left vitelline vein

W.

W.d. Wolffian duct

Y.

Y.s. Yolk stalk

Descriptions of Figures of Reconstructions and Dissections.

A number of illustrations of dissections and reconstructions of embryos of *Squalus acanthias* are to be found scattered through the literature of elasmobranch development[1]). These are, however, in most cases, illustrations of particular organs or systems and include only a limited series of stages. It has been thought that a series of figures showing general development of this form would be of value, and for that purpose the following graphic reconstructions, made from selected embryos of the normal plate series, have been added to the customary plates. There are included also figures of a short series of dissections of embryos selected with care to correspond with some of the later stages.

The general plan adopted has been to reconstruct all the important structures of the embryo as seen from the left side, with the skin and mesodermal structures — with the exception of the vascular system — removed. It has been necessary, however, to modify this plan in several particulars, and in connection with some embryos to introduce supplementary reconstructions. Thus the mesoderm has been included in the reconstructions of the first four embryos and mid-sagittal section views of embryos of 2.7 mm. and 3.5 mm. in length (N.P.S. 9 and N.P.S. 14) have been added. The arterial system and the heart are included in all the general reconstructions of embryos over four millimeters in length. The

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1) Among these may be mentioned those of:

a) The central nervous system.

JOHNSTON, J. B., 1909, The morphology of the forebrain vesicle in vertebrates. Journ. comp. Neur. and Psych., Vol. 19, p. 457—539.
v. KUPFFER, K., 1906, Die Morphogenie des Zentralnervensystems in HERTWIGs Handbuch d. vergl. u. exp. Entw. d. Wirb.
LOCY, W. A., 1895, Contributions to the structure and development of the vertebrate head. Journ. Morph., Vol. 11, p. 497—594.
— 1899, New facts regarding the development of the olfactory nerve. Anat. Anz., Bd. 16, p. 273—290.
— 1903, A new cranial nerve in selachians. Mark Anniversary Volume, p. 41—54.
NEAL, V. H., 1898, The segmentation of the nervous system in Squalus acanthias. Bull. Mus. comp. Zool. Harvard Coll., Vol. 31, p. 147—294.

b) The peripheral nervous system.

BROHMER, P., 1909, Der Kopf eines Embryos von Chlamydoselachus und die Segmentierung des Selachierkopfes. Jena. Zeitschr. f. Naturw., Bd. 44, p. 647—698.
JOHNSTON, J. B., 1909, loc. cit.
LOCY, W. A., 1895, loc. cit.
— 1899, loc. cit.
— 1903, loc. cit.
— 1905, On a newly recognized nerve connected with the fore-brain of selachians. Anat. Anz., Bd. 26, p. 33—123.
MEEK, A., 1909, The encephalomeres and cranial nerves of an embryo of Squalus acanthias. Anat. Anz., Bd. 34, p. 473—475.
NEAL, V. H., 1898, loc. cit.
PLATT, J., 1891, A contribution to the morphology of the vertebrate head. Journ. Morph., Vol. 5, p. 79—112.

c) The nasal pit.

BERLINER, K., 1902, Die Entwicklung des Geruchsorganes der Selachier. Arch. f. mikr. Anat., Bd. 60, p. 386—405.

d) The head somites.

BROHMER, P., 1909, loc. cit.
LAMB, A. B., 1901, The development of the eye muscles in Acanthias. Amer. Journ. Anat., Vol. 1, p. 185—202.
PLATT, J. B., 1896, loc. cit.

f) The urogenital system.

GREGORY, E. R., 1897, Origin of the pronephric duct in selachians. Zool. Bull., Vol. 1, p. 123—129.
MINOT, C. S., 1892, Human embryology, p. 236. [Mesonephric tubule.]

g) The vascular system.

HOCHSTETTER, F., 1906, Die Entwicklung des Blutgefäßsystems. HERTWIGs Handbuch d. vergl. u. exp. Entw. d. Wirb., Bd. 3, Tl. 2, p. 21—166.
PLATT, J. B., 1896, loc. cit.

h) The skull.

SEWERTZOFF, A. N., 1899, Die Entwicklung des Selachierschädels. Festschr. v. KUPFFER, p. 281—324.

venous system as a whole is only represented in Figure 10, a reconstruction of a embryo 7.5 mm. in length. Four reconstructions of the head somites follow the reconstructions of the general anatomy. The oldest embryo thus reconstructed is 9.0 mm. in length. For the later history of these structures in *Squalus acanthias* the reader is referred to the excellent paper by A. LAMB [1]) which includes a series of reconstructions of older stages.

Most of the reconstructions have been made from transverse sections and in the majority of cases every other section was drawn and used in the preparation of the figure. A few reconstructions have been made from sagittal sections by KASTSCHENKO'S [2]) method but when this has been done it is noted in connection with the description of the figure. It has been necessary to use several scales of magnification in the series as the smallest embryo is less than one-tenth the length of the largest one.

All the figures of reconstructions with the exception of the simple cut of the aortic arches (Fig. 14) are the work of Mr. WM. OLIVER. A liberal grant from the National Academy of Sciences made it possible to secure the services of this accomplished draughtsman. The use of various schemes of shading to represent different systems and organs is explained in the descriptions of figures. The dissections are all drawn with the camera lucida at a magnification of six diameters. It is hoped that they will bring out certain features, such as the general proportions of the viscera at different stages of development, which are not well illustrated by the reconstruction method.

Fig. 1. Graphic reconstruction of an embryo of 1.8 mm. in length. Normal plate series No. 6. (H.E.C. 984.) × 50.

The embryo is seen from the left. Uncut surfaces of ectoderm are shaded in longitudinal lines; entoderm is shaded in vertical lines; mesoderm is shaded in stipple. The yolk upon which the embryo rests is represented by diagonal black lines crossed with white. Ectoderm in cross section is indicated by oblique lines running from left to right; entoderm in cross section, by oblique lines running from right to left; mesoderm in cross section, in broken lines running from right to left. In the head region the ectoderm has been cut away at the median line. Behind the cephalic plate the ectoderm is cut to the left of the median line. The external surface of the archenteron and the lateral plate of mesoderm are exposed in the anterior part of the embryo. In the posterior part of the embryo the ectoderm, mesoderm, and entoderm are all cut back to a plane a little to the left of the median line. The entoderm in the head and anterior part of the trunk region is cut along the line where it spreads out over the blastodisc as a flat sheet.

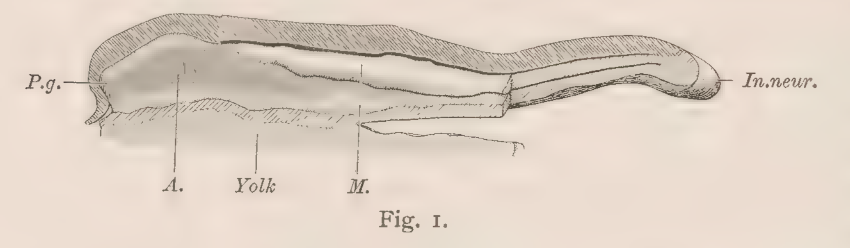


Fig. 1.

The archenteron (*A.*) is seen to be folded up into a shallow pouch, from the anterior end of which the preoral gut (*P.g.*) projects forward a little into the slight head fold. Laterally, the walls of the archenteron flatten out abruptly. The mesoderm (*M.*) appears as a narrow plate, triangular in cross section, lying above the archenteron. The anterior end of this plate is still fused with the entoderm and is indicated with a broken line.

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1) Loc. cit.

2) N. KASTSCHENKO, 1886, Methode zur genauen Rekonstruktion kleinerer makroskopischer Gegenstände. Arch. f. Anat. u. Phys., p. 388.

Fig. 2. Graphic reconstruction from sagittal sections of an embryo of 2 mm. Normal plate series No. 7. (H.E.C. 1009.) × 50.

The left side of the embryo is seen. The scheme of shading to indicate germ layers is the same as that employed in Fig. 1. The ectoderm is cut away a little to the left of the median line. The entoderm and mesoderm are seen as uncovered by the ectoderm, they are cut away along the plane where they extend out laterally into the blastodisc. At the posterior end of the embryo all the germ layers are cut in a plane a little to the left side of the median line.

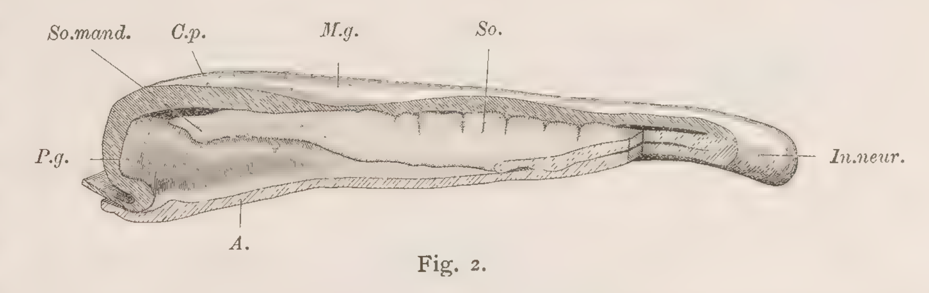


Fig. 2.

The cephalic plate (*C.p.*) is almost flat. Posterior to the cephalic plate there is a distinct though shallow medullary groove (*M.g.*) which gradually becomes flattened out posteriorly. The incisura neurenterica (*In.nevr.*) is deeper than in the preceding reconstruction. The head mesoderm extends forward under the cephalic plate, ending in a distinct dilatation — the beginning of the mandibular somite (*So.mand.*). Posterior to the mandibular somite the mesoderm and entoderm are still confluent, and their juncture is indicated by a broken line. Four distinct trunk somites (*So.*) are present. A fifth somite is probably forming anteriorly. Posteriorly the mesoderm spreads out over the blastodisc. Mesoderm, entoderm, and ectoderm are seen to fuse in the wall of the incisura neurenterica. The preoral gut (*P.g.*) extends forward in the head fold as a broad blunt process which is almost square in cross section. The walls of the archenteron flatten out rapidly laterally and posteriorly.

Fig. 3. Graphic reconstruction of an embryo 2.7 mm. in length. Normal plate series No. 9. (H.E.C. 997.) × 50.

The plan of reconstruction and method of indicating germ layers are the same as those employed in Figs. 1 and 2. The ectoderm is cut away at the median line, both dorsally and ventrally. The entoderm and mesoderm are cut, as in Fig. 1, along the line where they flatten out to form a part of the blastoderm. The extreme posterior end of the embryo is represented as cut sagittally at the median line.

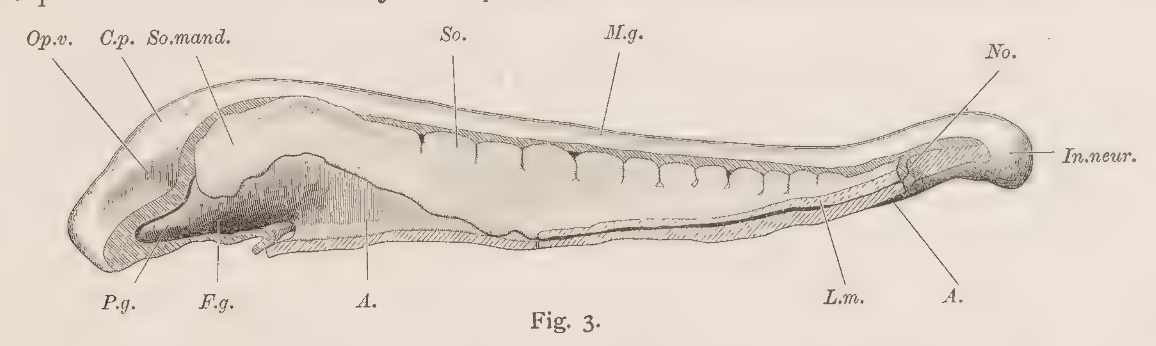


Fig. 3.

The cephalic plate (*C.p.*) is depressed, and the right optic vesicle (*Op.v.*) forms a deep lateral evagination in it. The medullary groove (*M.g.*) is of approximately the same depth throughout its length, and passes over into the incisura neurenterica (*In.neur.*) posteriorly. The mesoderm of the embryo extends forward to the cephalic plate as a narrow band, and ends in a distinct expansion, the mandibular somite (*So.mand.*). There are ten well formed trunk somites (*So.*) and an eleventh is in the process of formation posteriorly. The fore-gut (*F.g.*) extends forward to the cephalic plate. From its anterior wall, the preoral process (*P.g.*) projects anteriorly along the median line between the optic vesicles. The notochord (*No.*),

in this reconstruction, is seen only at the beginning of the sagittal section in the region. It is still attached to the roof of the archenteron at this point.

Fig. 4. Graphic reconstruction of an embryo 2.7 mm. in length. Normal plate series No. 9. (H.E.C. 997.) $\times$ 50.

This is another reconstruction of the embryo illustrated in the preceding figure. All structures, except the notochord, are sectioned along the median line, so that one sees the right side of the inner surfaces of the medullary groove and archenteron. The former structure shows points of interest not mentioned in the description of Fig. 3. The fore-gut portion of the archenteron extends forward to the cephalic plate, and from its base the preoral gut projects forward between the optic vesicles.

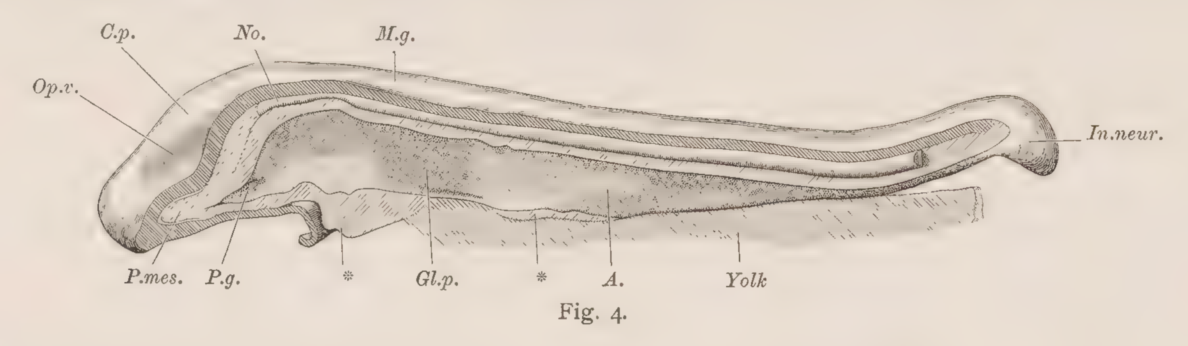


Fig. 4.

The first gill pouch is represented by an irregular lateral expansion of the fore-gut (*Gl.p.*). The archenteron posterior to the fore-gut is floored in part by irregular masses of cells; and these, where they cross the median line, are represented by the areas shaded in oblique lines (*, *). A large mass of preoral mesoderm has proliferated from the anterior wall of the archenteron, and is represented in the reconstruction as sectioned along the median line. It is shaded in broken oblique lines. So far as the notochord is a separate structure, it is shown as a rounded rod. At the anterior and posterior ends, where it fuses with the preoral mesoderm and the roof of the archenteron respectively, the notochord is cut along the median line. As indicated by the shading, all the germ layers become confluent in the anterior wall of the incisura neurenterica (*In.neur.*).

Fig. 5. Graphic reconstruction of an embryo 3.5 mm. in length. Normal plate series No. 14. (H.E.C. 982.) $\times$ 50.

The skin ectoderm is represented as cut away dorsally, a little to the left of the median line. At the anterior end of the head, the cut passes a little behind the large anterior neuropore (*An.neur.*), and then along the ventral median line of the head and pharyngeal region. The posterior end of the embryo is cut along the mid-sagittal line exposing the right internal surface of the medullary groove (*M.g.*) and incisura neurenterica (*In.neur.*). Both entoderm and mesoderm are cut away along the line where they flatten out upon the yolk.

The cephalic end of the medullary tube shows a marked ventral flexure. The optic vesicle (*Op.v.*) projects outward and backward from the expanded fore-brain. Above this region, and overlying the upper edge of the medullary tube, is a narrow cephalic crest (*C.ceph.*) which is represented in the figure in stipple. Although its ventral edge is extremely irregular, there is no division into separate nerve anlagen. The folds over the chordal portion of the medullary tube are fused from the hind-brain region to a point a little anterior to the beginning of the median sagittal section shown in the figure.

The mesoderm, which is represented in stipple, as in the preceding figures, extends forward into the head region as a flattened plate, and ends in the dilated mandibular somite (*So.mand.*). This structure is divided somewhat into an anterior expanded position, the somite proper, and a short, thick posterior stalk. The hyoid somite (*So.hyo.*) is a distinct anterior projection of the head mesoderm, above the stalk of the mandibular somite. Sixteen somites (*So.*) project from the dorsal edge of the mesoderm of the trunk region.

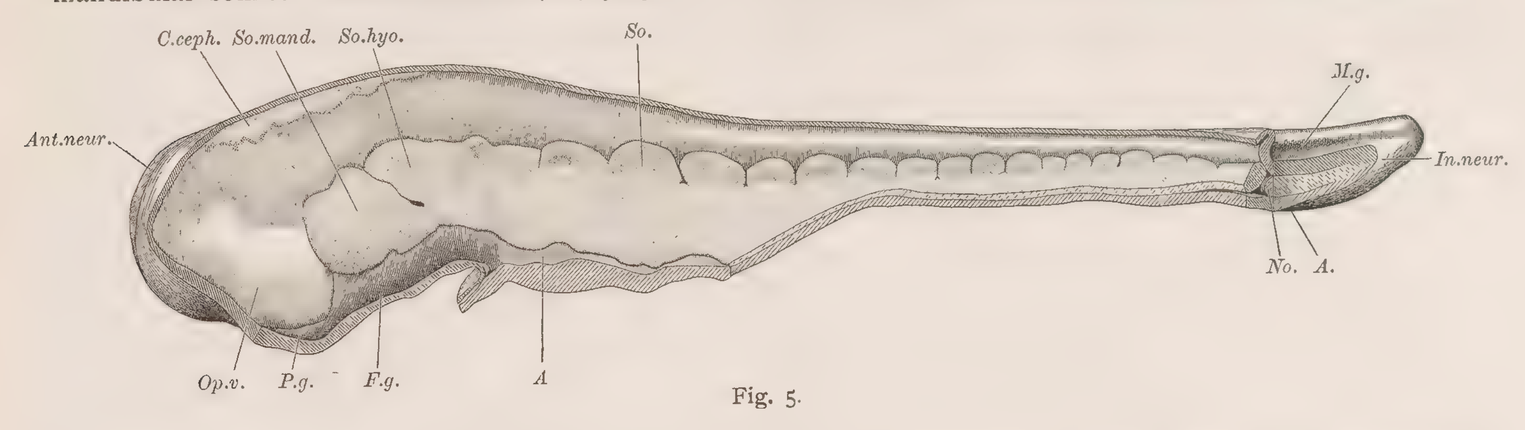


Fig. 5.

In only a few are there any evidences of an antero-posterior constriction of their bases, but the hases of all except the most posterior somites are a little constricted transversely.

Only a little of the fore-gut (*F.g.*) can be seen below the ventral border of the head mesoderm. The rounded preoral process (*P.g.*) projects forward from its anterior end, between and below the optic vesicles.

The notochord (*No.*) is also nearly covered by the mesoderm. It is seen partly in transverse, and partly in sagittal section, at the posterior end of the embryo.

Fig. 6. Graphic reconstruction of an embryo 3.5 mm. in length. Normal plate series No. 14. (H.E.C. 982.) $\times$ 50.

This is another reconstruction of the same embryo as illustrated in Fig. 5. The plan of reconstruction is similar to that employed in Fig. 4 — all structures except the notochord being sectioned in the median line.

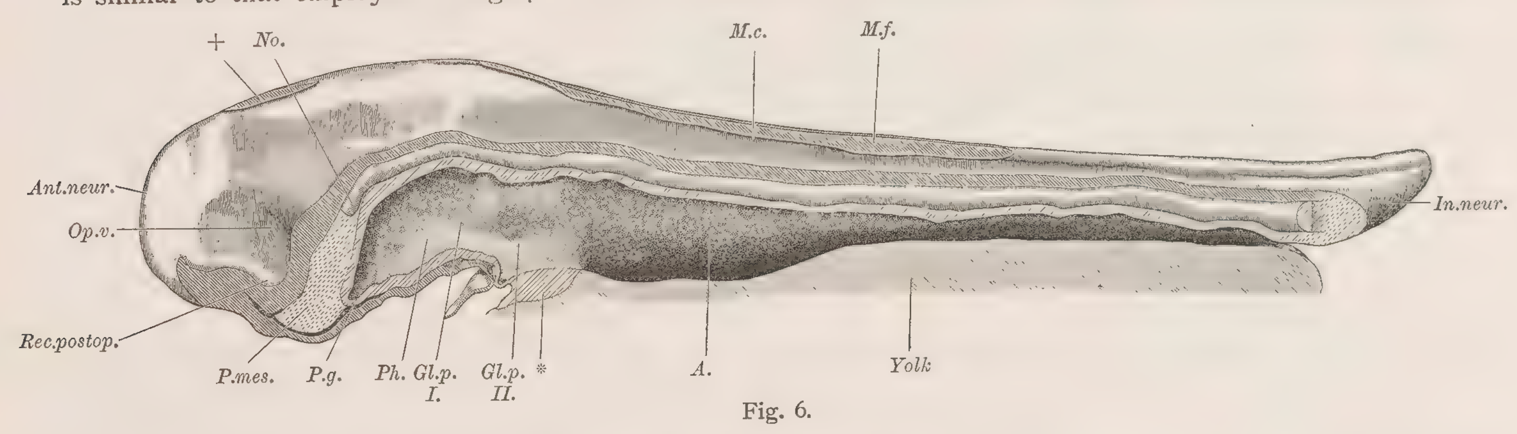


Fig. 6.

The anterior part of the medullary canal is closed except for the large anterior neuropore (*An.neur.*) and for a narrow slit in the hind-brain region. The roof of the mid-brain is seen in sagittal section (+). The left optic vesicle is seen as a deep pit extending laterally from the base of the fore-brain. Mesial to it is a deep median depression, the recessus postopticus or "infundibulum" (*Rec.postop.*). The medullary folds (*M.f.*) are fused from the hind-brain region to a point somewhat posterior to the middle of the trunk region.

The anterior wall of the pharynx (*Ph.*) is fused in part with the mass of preoral mesoderm (*P.mes.*) lying in front of it. From the base of the wall a small projection, the preoral gut, extends a little forward.

The first two gill pouches (*Gl.p.I, II*) appear as shallow depressions in the right wall of the fore-gut. Behind the fore-gut the archenteron is floored in part by a mass of entodermal cells (*), such as was described in connection with the reconstruction of an embryo 2.7 mm. in length (Fig. 4). The same method of shading is employed as in that figure. The notochord (*No.*) is extremely irregular in shape. Its anterior end is fused with the preoral mesoderm and the posterior end merges into the general cell mass in front of the incisura neurenterica (*In.neur.*).

Fig. 7. Graphic reconstruction of an embryo 4.0 mm. in length. Normal plate series No. 16. (H.E.C. 930.) × 33.

In this reconstruction, all structures of mesodermal origin have been omitted, with the exception of the preoral mesoderm which lies between the anterior wall of the gut and the floor of the brain, and which is sectioned at the median line. The skin ectoderm is cut along the median line except in the region of the anterior neuropore, where the line of section passes a little to the left. As in preceding reconstructions, the tail region is sectioned along the mid — sagittal line, showing the right half of the internal surface of the walls of the gut, medullary canal and neurenteric canal.

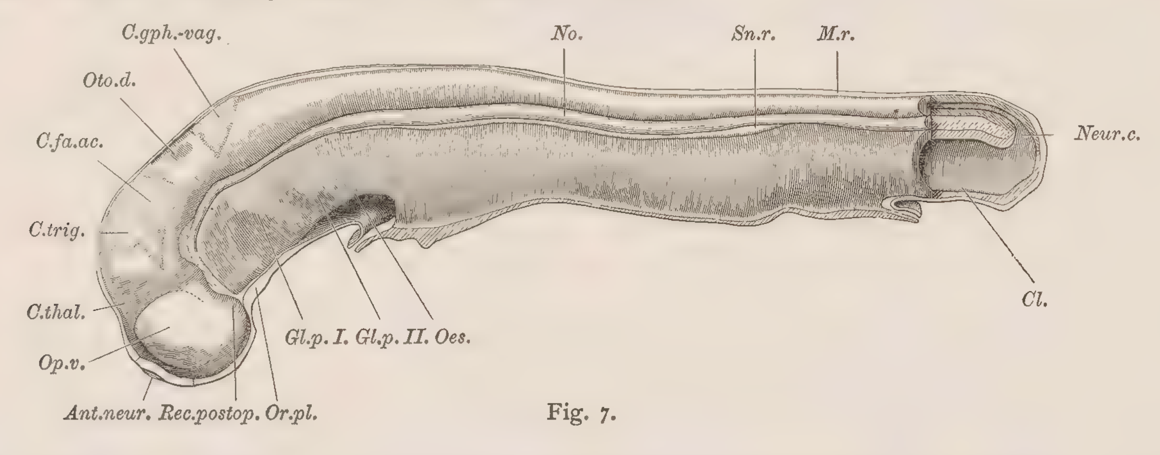


Fig. 7.

The fore-brain vesicle is bent downward and a little backward from the mid-brain. From its base projects a large shallow pouch, the primitive infundibulum or recessus postopticus (*Rec.postop.*). The optic vesicle (*Op.v.*) is broadly connected with the ventral zone of the fore-brain and extends forward and upward, overlapping the dorsal half of the lateral walls. There is a small anterior neuropore (*Ant.neur.*) the walls of which are almost in contact. The skin and neurectoderm are fused along the median line both posterior and anterior to it. A shallow groove separates the fore-brain and mid-brain, and a less marked one the mid-brain and hind-brain. A slight depression in the wall of the hind-brain indicates the position of the otocyst (*Oto.d.*).

The cephalic crest, which is indicated in stipple, is divided into two parts. The anterior division, which extends from the optic vesicles backward to the hind-brain, represents the anlagen of three nerve crests: the thalamic, facial-acoustic, and trigeminal. The thalamic crest (*C.thal.*) is represented by a small expansion above and posterior to the eye. The trigeminal and facial-acoustic crests (*C.trig., C.fa.-ac.*) are still confluent, but two small interruptions indicate the line of division between them. The posterior segment of the cephalic crest (*C.g-ph.-vag.*) represents the anlagen of both the glossopharyngeal and vagus crests, but as yet there is no differentiation of these two elements.

The archenteron is divided into fore-, mid- and hind-gut. The fore-gut consists of an expanded anterior portion, the pharynx (*Ph.*), and a short flattened oesophagus (*Oes.*). The floor of the anterior end of the pharynx is in contact, but not fused, with the thickened ectodermal portion of the oral plate

(*Or.pl.*). There are two gill pouches (*G.p.I, II*) — the first is a little more prominent than the second. The mid-gut is still broadly connected with the blastodermic entoderm; this connection, however, is much constricted transversely. The thickened plate of cells found at the anterior end of this connection, and so prominent a feature of younger embryos, is still present though in a less marked degree, in this specimen. The cloaca (*Cl.*) is represented by a very slight dilatation of the hind-gut — its floor is in contact, but not fused, with the skin ectoderm. The hind-gut is very slightly constricted behind the cloaca, but is broadly connected with the neurenteric canal (*Neur.c.*).

The anterior end of the notochord (*No.*) is bent sharply ventrally and merges into the preoral mesoderm. Its posterior end fuses with the entoderm and ectoderm of the anterior wall of the neurenteric canal. The hypochorda or subnotochordal rod (*Sn.r.*) forms a prominent median ridge on the roof of the gut, extending from the level of the second gill slit nearly to the end of the mid-gut. It is connected with the gut by a narrow neck along the median line.

Fig. 8. Graphic reconstruction of an embryo 4.8 mm. in length. Normal plate series No. 18. (H.E.C. 1398.) × 33.

The plan of this figure is similar to that of Fig. 7 of an embryo 4.0 mm. long, with the following exceptions. The skin ectoderm is represented as cut along the median line in the neuropore region, and as left in position over the oral plate and the first gill slit. The vascular system and a part of the pericardium are included in the reconstruction. The arteries are shaded with light broken transverse lines. The veins are represented in black crossed with white lines. The heart and pericardium are shaded in heavy stipple. The mesothelial layer of the heart is cut away at either end of the tube. The pericardium is represented as cut away dorsally above the dorsal mesocardium, and ventrally along the median line. Such a section exposes the internal surface of the right side of the pericardium.

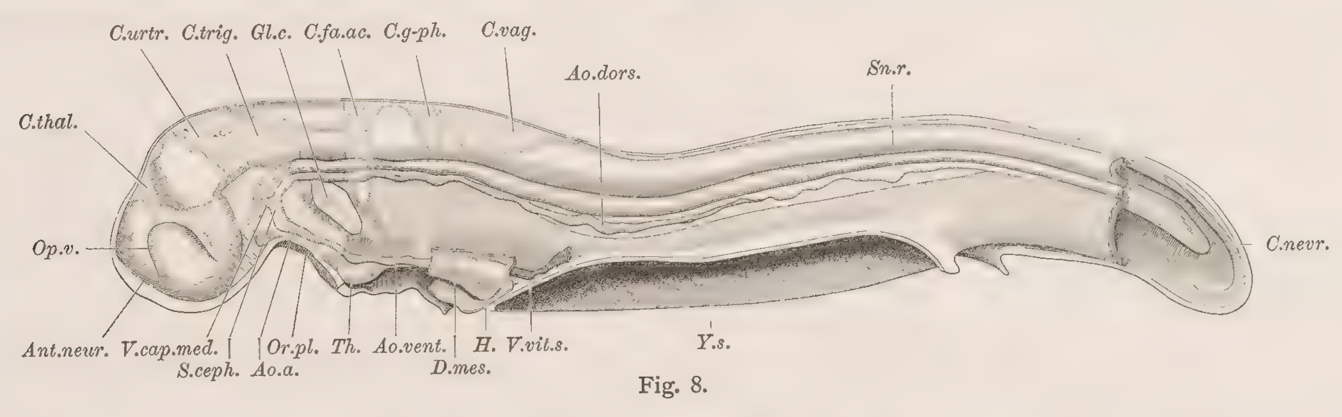


Fig. 8.

The fore-brain vesicle is much dilated. The anterior neuropore is now completely closed, but the skin and neurectoderm are still fused in this region (*Ant.neur.*). The optic vesicle (*Op.v.*) is similar to that seen in the reconstruction of the embryo 4.0 mm. in length. The trigeminal nerve crest (*C.trig.*) is broadly attached to the hind-brain and the posterior part of the mid-brain. The anterior part of this attachment extends upward to the dorsal median line. This portion of the crest represents the urtrochlearis (*C.urtr.*) of Dohrn and other authors. The connection between this anterior part and the main part of the crest is interrupted by two small openings which indicate the line along which the separation between the urtrochlearis and the trigeminus proper will take place. The ventral part of the trigeminal crest is divided into an anterior and a posterior limb. The anterior or ophthalmic portion lies mainly between the optic vesicle and the brain tube. It is continuous anteriorly with the thalamic crest (*C.thal.*). The posterior limb or

mandibular portion extends backward and downward in the mandibular arch. Its ventral edge becomes indistinguishable from the mesenchyma of this region. A narrow band of crest cells unites the thalamic and urtrochlear crests. The facial-acoustic crest (*C.fa.-ac.*) is completely separated from the trigeminal, but is connected by a narrow dorsal band with the glossopharyngeal crest (*C.g-ph.*). The glossopharyngeal and vagus (*C.vag.*) crests are now completely separated. The posterior end of the latter is continued some distance along the spinal portion of the medullary tube.

The pharynx is somewhat expanded anteriorly. Its floor is fused with the skin ectoderm in the oral region, forming the oral plate (*Or.pl.*). In the drawing the skin ectoderm is represented as cut away around the border of this fused area. The thyreoid gland (*Th.*) appears as a deep pouch from the floor of the pharynx, immediately behind the oral plate. Two gill pouches project from the side of the pharynx. The first is fused with the overlying ectoderm, which is represented in the figure as left in position. In this plate is a slight depression — the beginning of the first gill cleft (*Gl.c.*). The pharynx becomes continuous posteriorly with the short broad oesophagus. The yolk stalk (*Y.s.*) in this embryo is connected with approximately the middle half of the gut. The left wall is represented as cut away to a great extent, exposing the internal surface of the right wall. The cloaca (*Cl.*) is represented by a very slight dilatation of the hind-gut, and the postanal gut by a short, somewhat constricted segment of the tube, connecting the cloaca with the neurenteric canal (*Neur.c.*).

This is the first member of the series of reconstructions in which an attempt has been made to illustrate the vascular system. The veins of the blastoderm, which are not extensive, unite to form short vitelline veins, of which the left is shown in the figure (*V.vit.s.*). These remain bifurcated throughout the posterior half of the heart but unite anteriorly. The mesothelial layer of the heart is here represented in stipple. The ventral mesocardium is broken down, but the dorsal mesocardium (*D.mes.*) extends the entire length of the heart. The ventral aortae, of which the left is shown (*Ao.vent.*), are separate throughout. They are continuous with the first pair of aortic arches (*Ao.a.*). The aortic arches of the right and left sides become confluent dorsally, and from the chamber thus formed, the sinus cephalicus (*S.ceph.*), there extends forward a single vessel. This structure, which can only be followed through a few sections in the embryo, is represented as cut off near its origin. It represents the beginning of the vena capitis medialis (*V.cap.med.*). Below the sinus cephalicus there is a small dilatation of the aortic arch, which may represent the large ophthalmic artery. The dorsal aorta (*Ao.dors.*) extends backward a little beyond the middle of the trunk region. It is irregular in caliber, and in places is apparently solid.

The notochord (*No.*) is curved sharply downward at its anterior end. The posterior end is fused with the entoderm just anterior to the neurenteric canal. Below the notochord, from the level of the vagus crest backward, is seen the subnotocordal rod (*Sn.r.*). This structure is now larger proportionally than in later stages. It is attached to the roof of the pharynx anteriorly, and to the cloaca posteriorly. At several points along its free portion, it is enlarged and approaches the roof of the gut, although not in contact with it.

Fig. 9. Graphic reconstruction of an embryo 5.2 mm. in length. Normal plate series No. 20. (H.E.C. 1355.) × 50.

Only the anterior two-fifths of this embryo is reconstructed. The plan of reconstruction is similar to that employed in Fig. 8 except that the otocyst is shown in position, with the skin ectoderm cut away around its opening.

The fore-brain is still connected with the skin ectoderm in the region (*Ant.neur.*) where the anterior neuropore was formerly present, but this fusion is much less extensive than that seen in the reconstruction of the embryo of 4.8 mm. The thalamic nerve crest (*C.thal.*) is still connected with the trigeminal crest (*C.trig.*) by a slender cellular strand. The dorsal portion of the trigeminal crest or urtrochlearis (*C.urtr.*) is connected with the general mass of the trigeminal crest by an extremely irregular cellular band. That portion of the trigeminal crest which lies in the mandibular arch becomes indistinguishable from the mesenchyma ventrally, and its ventral termination is therefore only indicated by a broken line. The facial-acoustic crest (*C.fac.*, *C.ac.*) is somewhat enlarged at the level of the dorsal aorta. Here it is possible to distinguish between facial and acoustic portions, and the latter has been represented in coarse stippling. A small branch of the facial-acoustic crest passes a short distance backward over the external surface of the otocyst. The facial-acoustic crest, like the trigeminal crest, becomes indistinguishable from the mesenchyma ventrally. The

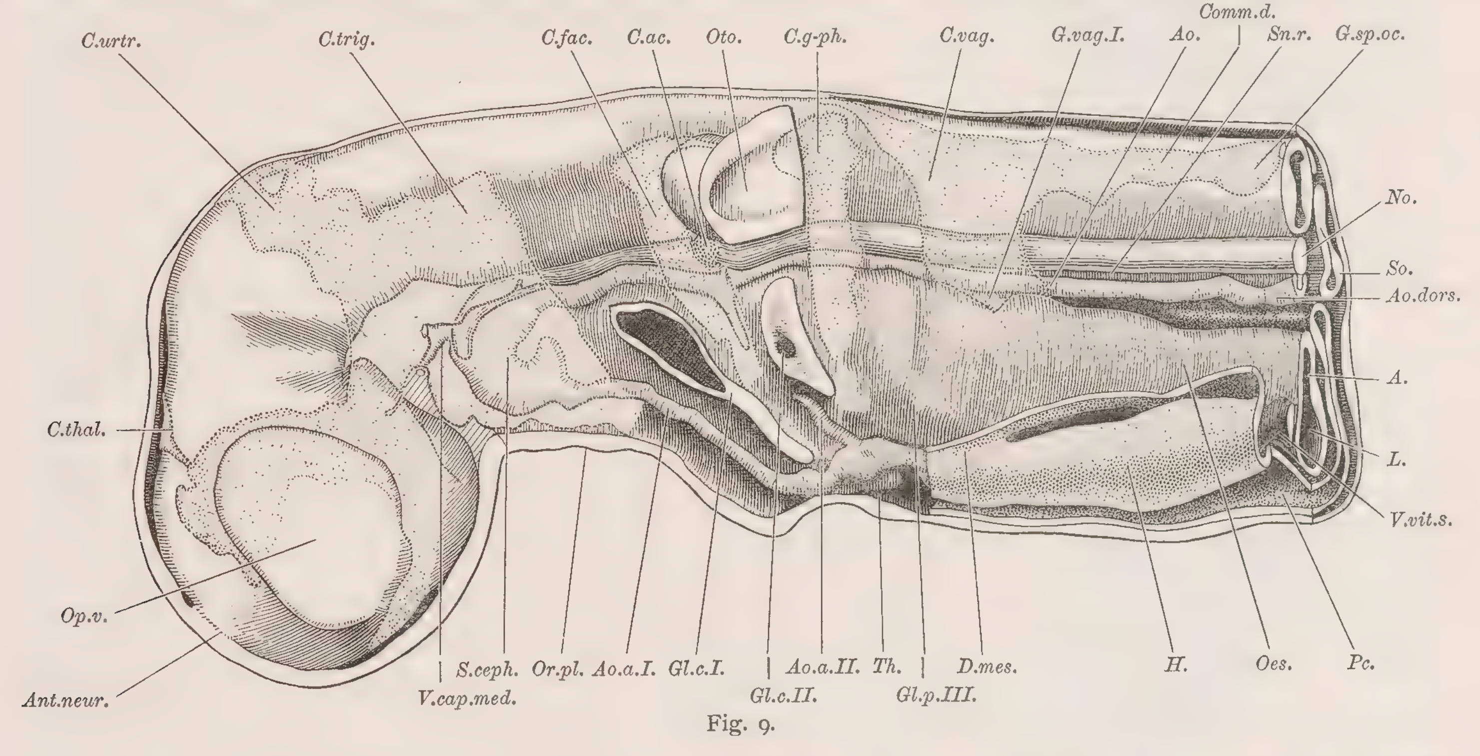


Fig. 9.

otocyst (*Oto.*) is deeply invaginated, but is still broadly connected with the skin ectoderm. The glosso-pharyngeal crest (*N.g.-ph.*) is completely separated from the vagus. The vagus crest (*N.vag.*) extends ventrally to the upper edge of the pharynx. From its ventral border there is a small projection (*G.va.I*) which probably represents the ganglion of the first branchial ramus of the vagus. There is also a small posterior prolongation, from which the remaining branchial ganglia probably arise. The vagus crest is broadly connected with the dorsal ganglion commissure (*Comm.d.*). The first spinal-occipital ganglion (*G.sp.-oc.*) is represented by an enlargement of this structure just above the posterior end of the heart.

The pharynx ends bluntly in front, and gradually narrows to form the oesophagus (*Oes.*) posteriorly. The first two gill slits (*Gl.s.*) are open in part, and the third gill pouch (*Gl.p.*) is in the process of formation. The thyreoid gland (*Th.*) appears as a small pouch projecting backward from the floor of the pharynx behind the second gill slit. The oesophagus is decidedly flattened transversely. At the level shown in cross section in the figure, it is about to join the vitelline duct. Its ventral part at this point is expanded into an ill defined pocket, the anlage of the liver (*L.*).

The mesothelial walls of the heart are represented in stipple. The dorsal mesocardium is in part broken down, and the dorsal connection thus established between the sides of the pericardial cavity is

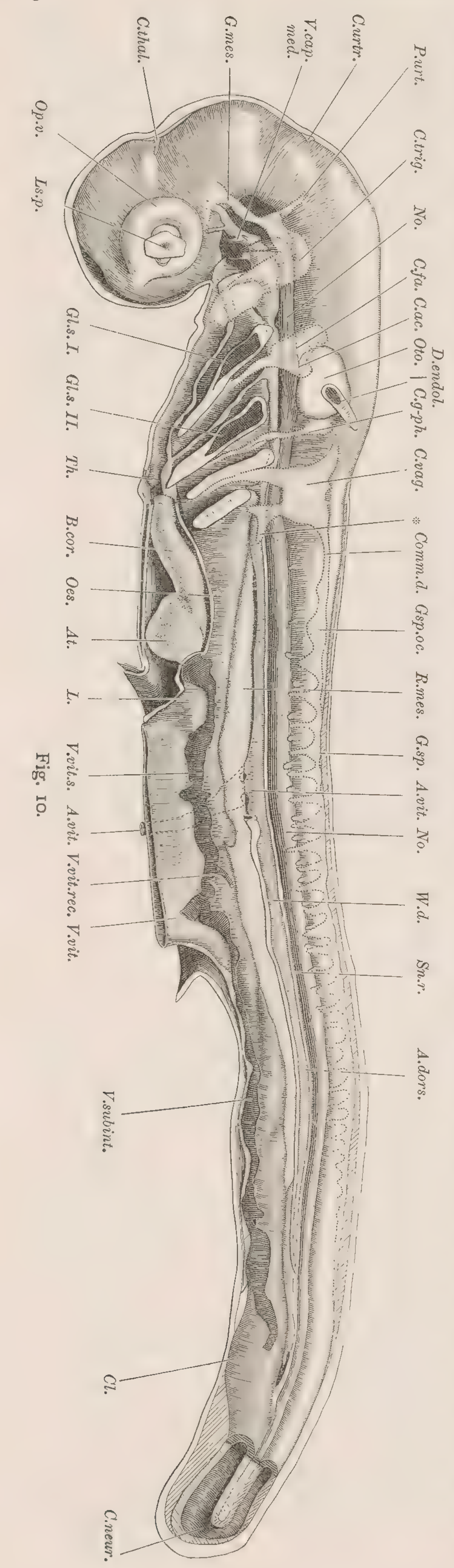


Fig. 10.

indicated in black. The upper part of the first aortic arch (*Ao.a.I*) forms an irregular, dilated chamber, from the anterior wall of which arise a pair of sprouts (*V.cap.med.*) which bifurcate almost immediately into anterior and posterior branches. These represent the anterior end of the vena capitis medialis. The second aortic arch (*Ao.a.II*) is not complete but is represented by branches from the dorsal and ventral aortae.

The notochord (*No.*) is bent ventrally at its anterior end. Below it, from the level of the vagus crest backward, is seen the subnotocordal rod (*Sn.r.*).

Fig. 10. Graphic reconstructian of an embryo 7.5 mm. in length. Normal plate series No. 22. (H.E.C. 1503.) × 33.

The general plan of reconstruction is similar to that of Figs. 8 and 9, with the exception that the veins and the Wolffian duct, which is left unshaded, are included.

There is no longer any connection in the neuropore region between the skin and neurectoderm. The optic vesicle (*Op.v.*) is now indented, forming the optic cup, and in the concavity thus formed lies the pear-shaped lens (*Ls.*). The lens is still broadly attached to the skin ectoderm, which is represented as cut away around the attachment. There is a deep lentic pit (*Ls.p.*). A shallow infundibular sac projects from the floor of the fore-brain. The thalamic (*C.thal.*), the urtrochlear (*C.urtr.*), and the trigeminal (*C.trig.*) crests are now completely separated. The first and second of these are much reduced in size. Two processes project from the anterior part of the trigeminal crest. The dorsal process (*Pr.urt.*) is the remnant of the former connection between the urtrochlear and trigeminal crests. The ventral process (*G.mes.*) is the anlage of the mesocephalic ganglion. The lower edge of this ventral process is expanded over the optic vesicle and is confluent with the mesenchyma of this region. The mandibular process of the trigeminal crest cannot be traced beyond the upper end of the mandibular arch. The acoustic portion of the facial-acoustic crest (*C.fa.*, *C.ac.*) extends a little over the lateral surface of the otocyst. The otocyst (*Oto.*) is connected with the skin ectoderm by a short broad duct from which a shallow groove extends upward and backward. The glossopharyngeal crest (*C.g-ph.*) shows no features of special interest. The first and second branchial processes of the vagus crest are clearly established. From the posterior border of the second, a narrow band of cells extends backward above the pharynx. The spinal nerve crest extends backward to the level of the cloaca. There are twenty-eight anlagen of spinal

nerve ganglia. The two ganglia of the spino-occipital nerves (*G.sp.oc.*) are represented by enlargements of the dorsal ganglionic commissure. The ventral roots of the two spino-occipital and the anterior fifteen spinal nerves are established.

The pharynx (*Ph.*) is somewhat flattened dorso-ventrally. From its anterior end projects the posterior portion of the hypophysis (*Hyp.*). The anterior portion of this structure is as yet not invaginated. The two anterior gill slits (*Gl.s. I, II*) are open, and the ectoderm and entoderm are confluent over the third and fourth pouches. In the figure, the skin ectoderm is represented as left in position over these fused areas. The oesophagus (*Oes.*) is long and slender. The liver (*L.*) arises from the gut at the juncture of the oesophagus and the vitelline duct (*D.vit.*). The pancreas is here seen for the first time in the series of reconstructions. It is a small pouch (*Panc.*) from the dorsal wall of the gut, over the middle of the vitelline duct. The rotation of the gut to the left is already begun. This process has produced a shallow groove (*L.g.*) which extends the entire length of the left wall of the yolk stalk. The spiral valve (*Sp.v.*) at this stage appears as a shallow groove in the wall of the epithelial tube of the intestine. It arises on the left side of the yolk stalk, posterior to the pancreas, and makes a little more than one complete turn about the gut. The cloaca (*Cl.*) is somewhat dilated and its floor is in contact with the skin ectoderm below it.

The Wolffian duct (*W.d.*), although present in the embryos of this series from 3.8 mm. in length upward, is here represented for the first time in the series of reconstructions. It has been left unshaded. It arises anteriorly from a long groove in the dorsal wall of the coelom and from this groove arise also the pronephric tubules. To avoid obscuring the origin of the vitelline artery, the anterior end of the duct has been omitted, and the structure is represented as cut across at the lower end of the coelomic funnel described above.

The sinus venosus, atrium (*At.*), ventricle (*V.*), and bulbus cordis (*B.cor.*) are to some extent differentiated. The dorsal mesocardium is entirely absent except at the extreme anterior end of the heart. The first and second aortic arches are completely formed. The third is represented by sprouts from the dorsal and the ventral aortae, and the fourth by a sprout from the dorsal aorta only. The vitelline artery (*A.vit.*) arises by two trunks (the remains of the two anterior right pronephric arteries) and passes ventrally on the right side of the yolk stalk. That part of its course which lies behind the right wall of the radix mesenterica (*M.mes.*) and the yolk stalk is drawn in broken lines. The third pronephric artery appears as a slight swelling behind the posterior root of the vitelline artery. The vena capitis medialis (*V.cap.med.*) is still broadly continuous with the dorsal aorta. No distinct vessel can be traced beyond the posterior edge of the trigeminal crest, but occasional irregular chambers, connected with the dorsal aortae, were present behind this point, in the position occupied later by the posterior part of the v. capitis medialis. While it is possible that they represent portions of a partially collapsed but continuous vessel, no such structure can be traced in the sections. The left vitelline vein (*V.vit.s.*) passes from the heart between the lobe of the liver diverticulum and the gut, and backward along the groove in the wall of the yolk stalk, described above. Near the end of the vitelline duct it receives the subintestinal vein and, passing abruptly ventrally, goes to the blastoderm. Anterior to this union with the subintestinal vein, it gives off small dorsal shoot which has been termed the recurrent vitelline vein (*V.vit.rec.*), and which later unites with the vitelline vein of the right side. At this stage the vitelline vein of the right side is much smaller than that of the left and is not connected with the subintestinal vein. It does not extend to the blastoderm. The subintestinal vein (*V.subint.*) is single throughout the greater part of its course, but bifurcates in front of the cloaca. Both right and left branches end blindly after passing a short distance upward on the walls of the cloaca.

Fig. 11. Graphic reconstruction of an embryo 9.0 mm. in length. Normal plate series No. 23. (H.E.C. 1495.) × 33.

A somewhat simpler method of representation has been employed for this reconstruction. The central nervous system and the digestive tract have been left in white, except where shading was necessary to bring out important changes in contour. The veins have been omitted.

The thalamic nerve crest is absent, but there is still a small urtrochlearis (*C.urtr.*). The trigeminal nerve crest (*N.trig.*) is much as in the preceding reconstruction, with a more distinct anlage of the mesocephalic ganglion (*G.mes.*). The facial-acoustic (*N.fa.-ac.*) and glossopharyngeal (*N.gl.-ph.*) crests need no special description. There are three anlagen of branchial ganglia of the vagus (*N.vag.*) established. The first spinal-occipital ganglion is only indicated by a slight swelling of the dorsal commissure — it has no ventral root. The second spinal-occipital ganglion (*G.sp.oc.*) is well established. The ganglia and ventral roots of all the spinal nerves shown in the figure are in contact.

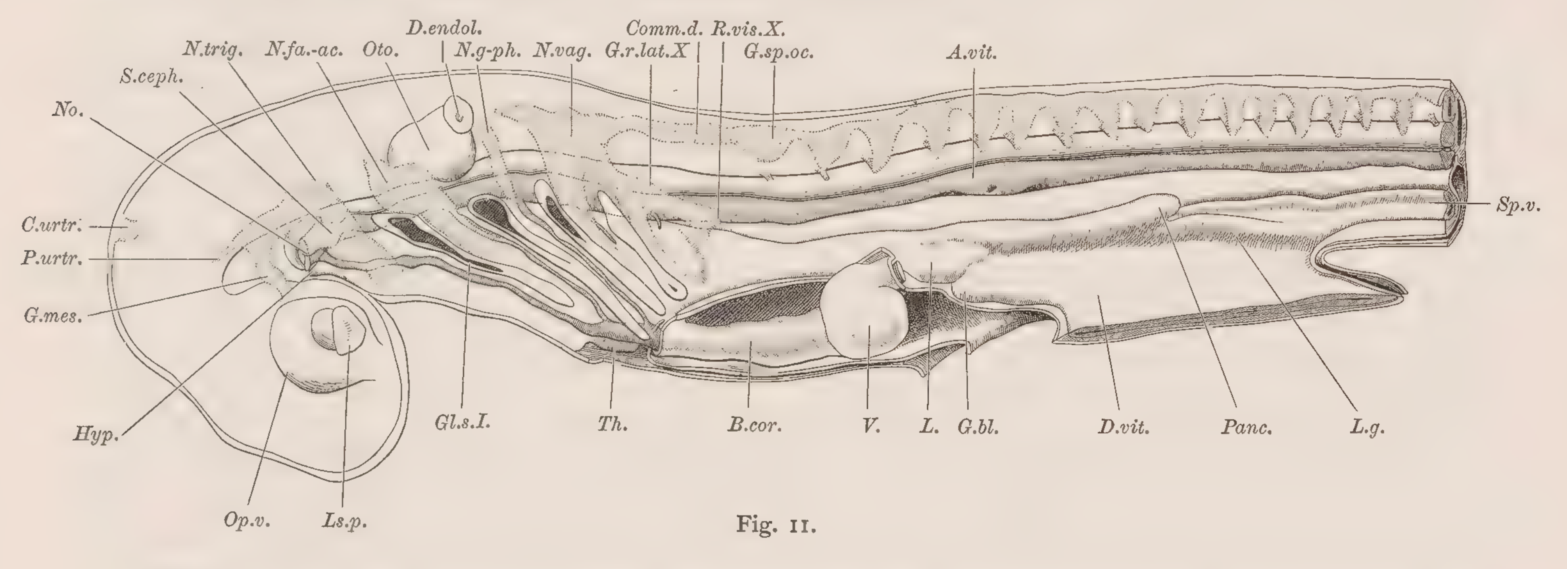


Fig. 11.

The pharynx has the same general outline as that seen in the reconstruction of the embryo, and the hypophysis (*Hyp.*) and thyreoid (*Th.*) are in about the same stage of development. The four anterior gill slits (*Gl.s.*) are open in part, and the fifth gill pouch is established. The liver consists of a ventral pouch (*Li.*). The pancreas (*Panc.*) needs no special description. The lateral groove (*L.g.*) of the vitelline duct (*D.vit.*) extends from the liver to the anterior end of the intestine. The groove of the spiral valve (*Sp.v.*) is also well marked.

The division of the heart into sinus venosus (*S.v.*), atrium (*At.*), ventricle (*V.*), and bulbus (*B.cor.*) is indicated. The three anterior aortic arches are complete. The fourth and fifth are represented by arterial sprigs from the dorsal and ventral aortae. Only the upper part of the vitelline artery (*A.vit.*) is figured.

The subnotocordal rod (*Sn.r.*) is seen above the aorta from the level of the vitelline artery backward.

Fig. 12. Graphic reconstruction from sagittal sections of an embryo 11.5 mm. in length. Normal plate series No. 24. (H.E.C. 208.) × 33.

The general method representation of this reconstruction is similar to that of Fig. 11, which is of the preceding embryo in the normal plate series. The Wolffian duct has been included in this reconstruction.

The fore-brain vesicle is now distinctly divided into telencephalon (*Telen.*) and diencephalon. It is flexed until its original antero-posterior axis lies in the vertical plane of the head. There is a well

marked infundibulum with which the hypophysis (*Hyp.*) is in contact. The epiphysis (*Epi.*) and paraphysis (*Pa.*) form two distinct swellings from the roof of the diencephalon. The sulcus rhombo-mesencephalicus is well marked. The optic vesicle (*O.pv.*) is now decidedly cup-shaped, and the lens (*Ls.*) is completely separated from the ectoderm. The otic vesicle (*Oto.*) is connected with the skin ectoderm by a long slender endolymphatic duct (*D.endol.*). The thalamic and urtrochlear crests have entirely disappeared. The first of the eye muscle nerves, the oculomotor (*N.oc.*) is well established and is connected at its distal end with the ciliary ganglion (*G.cil.*). The ganglion of the trigeminus (*N.trig.*) is shaped like an inverted V, as in the preceding stages. There is still present a narrow ganglionic filament — the remains of the old urtrochlear process (*Pr.urt.*). The mesocephalic ganglion (*G.mes.*) is expanded. It is connected by a few slender strands with the ciliary ganglion (*G.cil.*), which lies directly mesial to it. Both the mandibular (*R.md.V*) and the maxillary (*R.mx.V*) ramus of the trigeminus are well developed. The facial-acoustic nerve complex (*N.fa.-ac.*) is also well advanced. The hyoid ramus (*R.hyo.VII*) extends half way down the second arch. The superficial ophthalmic ramus is absent on the left (reconstructed) side but is present on the right side.

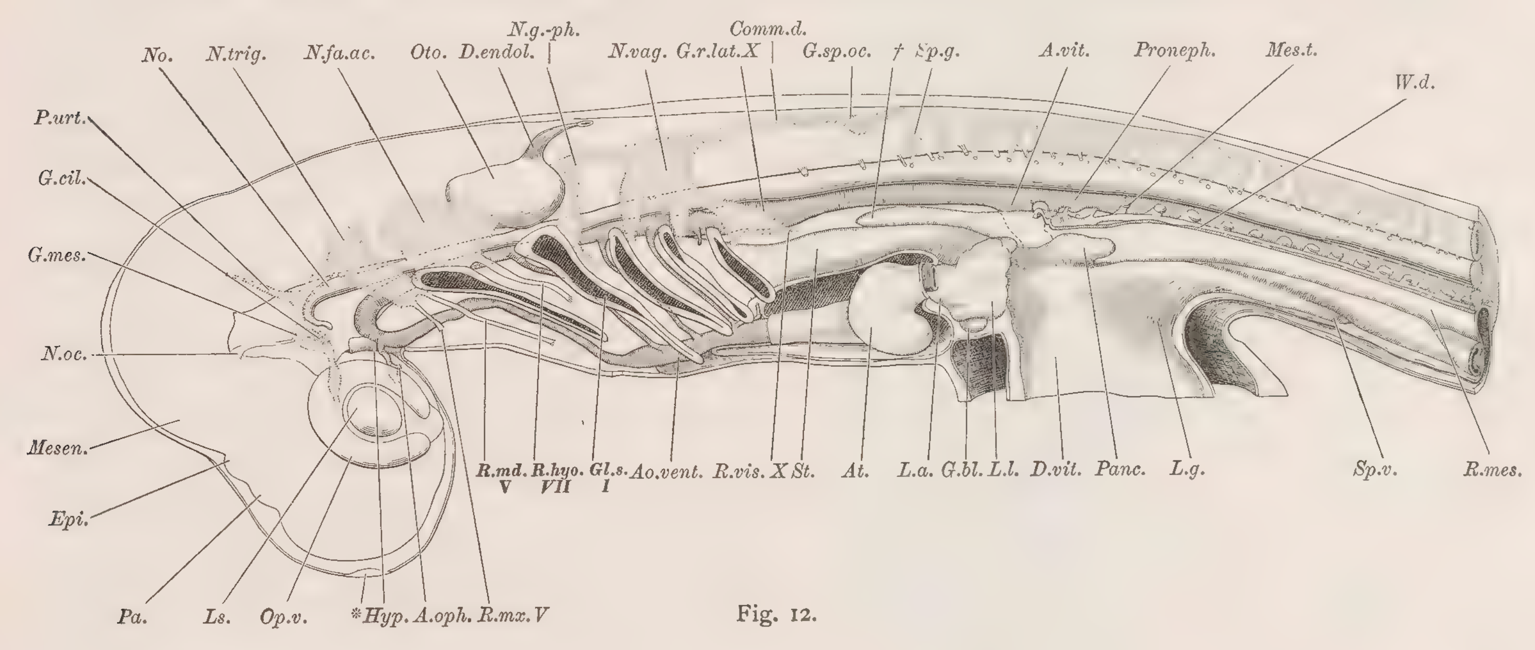


Fig. 12.

The glossopharyngeal (*N.g.-ph.*) and vagus (*N.va.*) crests are connected by a narrow dorsal commissure. The three anterior branchial ganglia of the vagus are established, and that part of the crest lying posterior to these is slightly divided into an upper lateral ramus portion (*G.r.lat.X*) and a lower portion, from which the remaining branchial ganglia will form and from which the visceral ramus (*R.vic.X*) will arise at a later stage. No special description need be given of the spino-occipital and spinal nerves. The dorsal and ventral roots of the latter have united, although in the reconstruction they are indicated as cut away proximal to the point of union.

The pharynx is markedly elongated and the first five gill slits open to it. The hypophysis (*Hyp.*) is well marked. The thyreoid now lies between the two ventral aortae and is completly hidden by them. The main divisions of the liver are present at this stage. A small anterior diverticulum (*L.a.*) extends forward between the vitelline veins. The left lateral pouch (*L.l.*) extends upward a little above the dorsal wall of the gut, and is joined below with the median chamber. From the base of the median chamber projects a small rounded pocket, the anlage of the gall bladder (*G.bl.*). The pancreas (*Panc.*) is still broadly attached to the dorsal wall of the gut but the connecting stalk is somewhat constricted transversely. The groove (*L.g.*) in the left wall of the vitelline duct (*D.vit.*) is a little more pro-

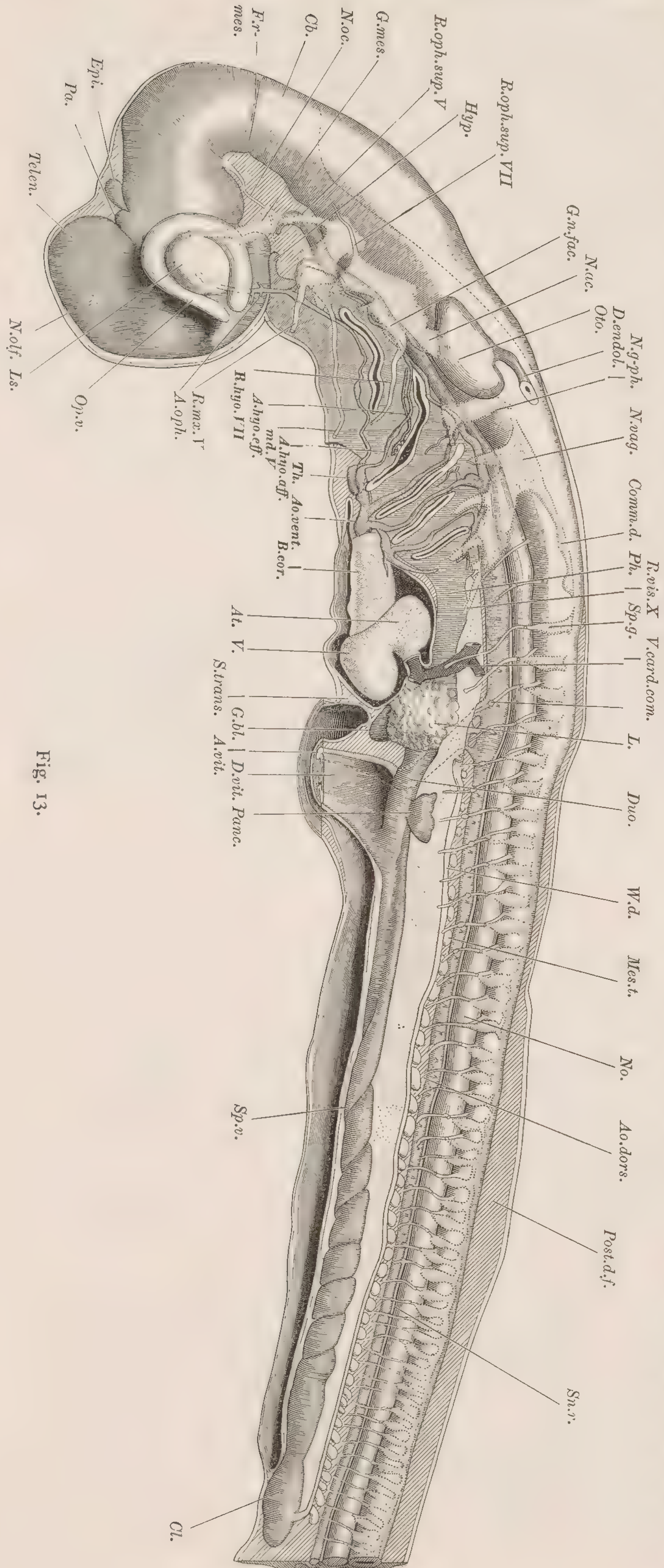


Fig. 13.

nounced than in the preceding stage. The Wolffian duct (*W.d.*) opens into the coelom above the pancreas. Above this opening, which in the reconstruction is covered by the mesothelial lining of the body cavity, are two small pronephric tubules (*Proneph.*). The mesonephric tubules (*Mes.t.*) are broadly connected with the coelom and, looping over the Wolffian duct, end in slight expansions.

The atrium (*At.*) and ventricle of the heart are separated by a slight constriction. The pericardial cavity is cut off from the coelom at the median line by the septum transversum There are four complete aortic arches and the fifth is in the process of formation. The vena capitis medialis is now completely separated from the aorta. As in the preceding reconstruction, the vitelline artery (*A.vit.*) arises from two trunks, and behind the second root, the third pronephric artery forms a marked dilatation of the aorta.

Figs. 13 and **14.** Graphic reconstructions of an embryo 15 mm. in length. Normal plate series No. 26. (H.E.C. 227.) Fig. 13 $\times$ 18, Fig. 14 $\times$ 33.

In Fig. 13 a return is made to the general style of illustration employed in Fig. 10. However, no attempt has been made to represent by shading the moulding of the lateral surface of the pharynx and all the veins except the common cardinals and the proximal end of the vitelline have been omitted.

The telencephalon (*Telen.*) is widely expanded, and the deep infundibular sack is curved a little cranially. The velum transversum and the paraphysis (*Pa.*) are well marked. Behind the paraphysis is the elongated epiphysis (*Epi.*) which is now distinctly divisable into an expanded distal portion and a narrower proximal stalk. The mesencephalon is somewhat expanded and is sharply marked off from the hind-brain posteriorly by a distinct rhombo-mesencephalic fissure (*F.r.-mes.*). The hind-brain

is elongated and much expanded dorsally. The boundary between the thickened lateral walls and the ependymal roof is indicated by a dotted line. Between the rhombo-mesencephalic fissure and the anterior end of this dotted line is a thickened segment of the roof of the hind-brain, the anlage of the cerebellum (*Cb.*). The spinal chord needs no particular description. The area of origin of the olfactory nerve (*N.olf.*) is indicated on the wall of the fore-brain. The oculo-motor nerve (*N.oc.*) is similar in position and relations to that of the preceding reconstruction. The trigeminal nerve, however, exhibits several important changes. Above the mesocephalic ganglion (*G.mes.*) arises two minute branches, the upper of which is the superficial ophthalmic ramus (*R.oph.sup.V*). The mandibular and maxillary branches of the trigeminus extend ventrally to the base of their respective arches and are shown in the reconstruction as cut off near their distal ends. The ganglionic mass of the facial-acoustic complex is divided definitely into a posterior acoustic part (*N.ac.*) and an anterior facial portion. The latter shows some subdivision into hyoid, buccal, and superficial ophthalmic portions. From the anterior end of the last the superficial ophthalmic ramus (*R.oph.sup.VII*) extends forwards to a point anterior to the cephalic edge of the ganglion of the trigeminal nerve. The hyoid ramus (*R.hyo.VII.*) extends to the base of the hyoid arch. The glossopharyngeal nerve (*N.g.-ph.*) needs no special description. Four branchial divisions of the vagus ganglion (*N.vag.*) are present in this embryo. They are represented as cut off near their origin from the general ganglionic mass. The visceral ramus (*R.vic.X*) is prolonged backward dorsally and laterally to the oesophagus to the mid cardiac region. A slight enlargement of the posterior dorsal angle of the general ganglion of the vagus represents the point of origin of the lateral line ramus. The upper dorsal ganglionic commissure (*Comm.d.*) connects the posterior border of the vagus ganglion with the first and second spinal-occipital ganglia. These two structures which appear only as enlargements of the dorsal ganglion of the commissure are not connected with their ventral roots which are seen directly below them. There are fourty seven spinal ganglia (*Sp.g.*) in the trunk region anterior to the posterior end of the cloaca. The dorsal ganglionic commissure, which until this stage has connected the spinal ganglia, is now broken down between the anterior twelve ganglia and between five ganglia of the mid trunk region. The entire length of the spinal nerves has been represented in the reconstruction. Their elongation in the regions of the pectoral and pelvic fins is quite noticeable. Sympathetic ganglia (*Symp.*) are present upon the ventral rami of the spinal-occipital nerves and anterior forty-one spinal nerves. The dorsal rami of the spinal nerves are represented as cut off near their origin from the nerve trunk.

The optic vesicle (*Op.v.*) is elongated and deeply cup-shaped. In it is lodged a large egg-shaped lens (*Ls.*). The otocyst (*Oto.*) needs no special description. The ductus endolymphaticus (*D.endol.*) still opens to the ectoderm by a long furrow.

It has been necessary to give a rather diagrammatic view of the pharynx because of the great growth of the gill clefts. These structures are represented as cut off close to their origin from the pharynx. The hypophysis (*Hyp.*) extends forward from the anterior end of the pharynx and lies in contact with the upper wall of the infundibulum. It is slightly expanded at its cranial extremity. The thyreoid gland (*Th.*) is somewhat obscured in the figure by the ventral aorta. Its dorsal outline, however, is represented by dotted lines. It can be seen that it is attached to the pharynx along the anterior half of its dorsal surface. The pharynx is abruptly constricted immediately behind the fifth gill cleft, passing over into the rather elongated oesophagus. The stomach, which is obscured in the figure by the lateral lobes of the liver (*L.*), is but little larger in caliber than the oesophagus. That portion of the gut which represents the duodenum (*Duo.*) is slightly less in caliber than is the stomach, and is directed a little ventrally; this bending is the first indication of the duodenal loop. The vitelline duct (*D.vit.*) now enters mainly on the right side of the intestine. Eight turns of the spiral valve (*Sp.v.*) are present. The intestine is much constricted just anterior

to the cloaca. The cloaca (*Cl.*) is somewhat elongated and the middle third of its floor is in contact, but not fused, with the thickened anal plate of ectoderm. The lateral lobes of the liver (*L.*) extend upward above the dorsal wall of the gut. Secondary pouches are forming in large numbers from the walls of the main chambers. The anterior lobe, which is obscured in the figure by the sinus venosus, is as yet smooth. The gall bladder (*G.bl.*) now is present as a large ventral pouch the posterior end of which is entirely cut off from the median chamber of the liver. The pancreas (*Panc.*) is connected with the dorsal wall of the intestine upon the right side, by an elongated, laterally constricted neck. Three secondary pouches are forming from the roof of the pancreas. The Wolffian duct (*W.d.*) opens into the body cavity anteriorly. It is fused posteriorly with the lateral wall of the cloaca near its dorsal boundary. Forty-one mesonephric tubules (*Mes.t.*) are present, the anterior three being exceedingly small. None of the tubules are fused with the Wolffian duct, but all except the three anterior overlap this structure to some extent. The pericardial cavity (*Pc.*) is completely cut off from the coelom along the median line by the septum transversum (*S.trans.*). The atrium (*At.*) now lies almost entirely dorsal to the ventricle (*V.*) and is connected with it by a distinct atrioventricular canal.

This is the first embryo of the series in which the development of the efferent and afferent branchial blood vessels from the aortic arches is indicated. This stage has seemed of sufficient interest to require more detailed illustration than that given in the general reconstruction, and for this purpose Fig. 14, a somewhat more enlarged and slightly diagrammatic view of the same structures has been added. The description following applies equally to Figs. 14 and 15 as the same nomenclature is employed in both. The first aortic arch (*Ao.a.I*) is much reduced in caliber, except for a small dilated portion which lies immediately under the posterior part of the first gill eleft, and which represents the position in which the capillary system of the spiracular demi-branch will be formed. Anteriorly the first aortic arch joins with its fellow of the opposite side forming the base of the sinus cephalicus (*S.ceph.*). The deep ophthalmic artery (*A.oph.*) arises just anterior to this juncture and runs forward mesial to the optic cup. The second aortic arch gives off by two small channels a small and somewhat irregular parallel vessel which represents the second or hyoid afferent artery (*A.hyo.eff.*). Near its ventral extremity this vessel gives off four small vascular sprouts which pass into the gill filaments of this arch. The efferent arteries (*A.br.eff.*) of the third and fourth arches are represented by two "T"-shaped vessels springing from the anterior surfaces of the respective aortic arches near their dorsal ends. As yet no efferent vessel is represented in the fifth aortic arch. The sixth aortic arch is incomplete but vascular sprouts extend upward and downward from the ventral and dorsal aorta respectively. The dorsal sprout is joined with the fifth arch by a broad channel. From the base of the sixth arch a small vascular sprout passes backward for a short distance over the surface of the pericardium. A small vascular sprout also extends backward from the base of the dorsal sprout of the sixth arch. The segmental arteries (*A.seg.*) of the dorsal aorta are established throughout the greater part of the trunk region. The vitelline artery (*A.vit.*) arises by three distinct roots. In all other members of the series this vessel arises by two roots and the third or posterior root is represented by a slight enlargement on the left side of the aorta. The veins shown in Fig. 13 hardly need description. The

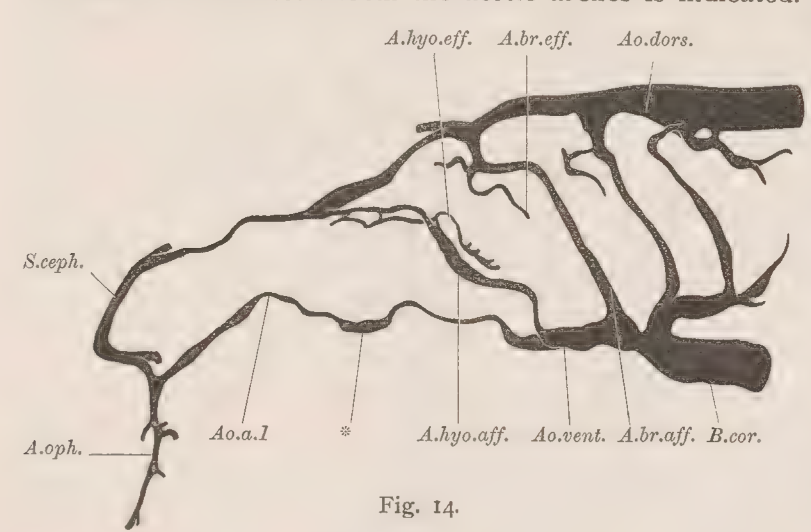


Fig. 14.

sinus venosus receives on either side a vitelline vein (*V.vit.*) and a common cardinal (*V.card.com.*). The latter breaks up into the posterior and anterior cardinals in the usual manner.

Fig. 15. Graphic reconstruction from sagittal sections of the anterior half of an embryo 18.0 mm. in length. Normal plate series No. 27. (H.E.C. 204.) × 33.

The plan used in the representation of this reconstruction is the same as that employed in Figs. 11 and 12. It has been necessary, however, to omit the optic vesicle and lens, and to represent the gill slits as cut off close to their origin from the pharynx. The use of sagittal sections does not permit of accurate reconstruction of the branchial blood vessels so these structures are also represented as cut away close to their origin.

The widely expanded telencephalon (*Telen.*) now extends forward decidedly over the roof of the tube-like diencephalon. The optic stalk (*Op.s.*) is shown in cross section. Its anterior wall is markedly thickened by the invasion of optic fibers. The epiphysis (*Epi.*) and paraphysis (*Pa.*) are seen as two prominent structures springing from the roof of the diencephalon. The infundibular sack is somewhat obscured by the structures overlying it. It is bounded above by shallow lateral grooves. The mesencephalon is somewhat expanded and is sharply separated from the hind-brain by the deep rhombo-mesencephalic fissure (*F.r.-mes.*). The anlage of the cerebellum forms a small but distinct thickening on the roof of the hind brain. There is no distinct line division between the myelencephalon and the cord. The oculomotor nerve (*N.oc.*) extends backwards to the level of the optic stalk. The mesocephalic ganglion (*G.mes.*) is connected with the anterior end of the main ganglion

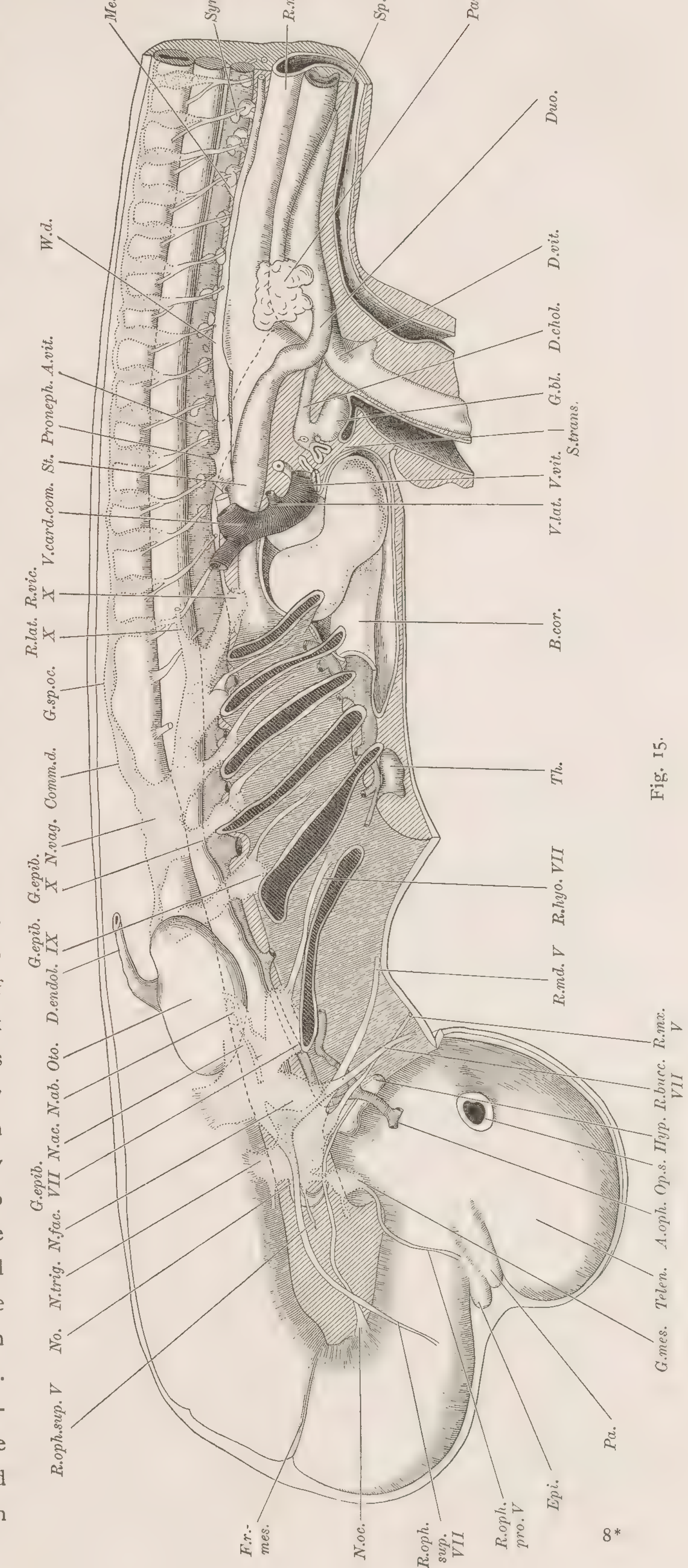


Fig. 15.

of the trigeminal nerve by a short ganglionic commissure. From the anterior edge of this commissure there projects forward a small filament, the superficial ophthalmic ramus of the trigeminal nerve (*R.oph.sup.V*). It extends ventrally from the mesocephalic ganglion nearly to the roof of the diencephalon. Both the mandibular and maxillary rami of the trigeminal nerve (*R.md.V; Rm.x.V.*) extend to the base of the first gill arch. In the reconstruction they are represented as cut off about the middle of their course. The facial complex presents several features decidedly different from those seen in the preceding reconstruction of an embryo 15 mm. in length. The superficial ophthalmic ramus (*R.sup.oph.VII*) extends forward to the anterior border of the mid-brain. The buccal ramus (*R.bucc.VII*), the ganglion but not the nerve of which was present in the preceding embryo, now extends to the base of the first arch. The epibranchial ganglion (*G.epib.VII*) is well marked and the hyoid ramus (*R.hyo.VII*) extends to the base of the second arch. The acoustic nerve (*N.ac.*) needs no special description. The abducent nerve (*N.ab.*) is entirely covered by the facial complex and by the otocyst and is represented in dotted lines in the figure. It springs by three roots from the floor of the hind-brain mesial to the otocyst. This structure (*Oto.*) is somewhat broader in proportion to its length than was the otocyst in the preceding reconstruction. The sacculus (*Sac.*) is represented by a large ill defined pouch in the floor. The glossopharyngeal nerve shows no feature of special interest aside from the well established epibranchial ganglion (*G.epib.IX*). The first three epibranchial ganglia of the vagus are clearly established and the corresponding branchial rami extend about half way down their respective arches. The lateral line ramus (*R.lat.X*) extends backward to the level of the duodenum, but in the figure it is represented as cut off near its origin from the ganglion. The visceral ramus (*R.vis.X*) extends backward to the anterior end of the stomach. The spinal — occipital ganglia are represented by two enlargements of dorsal ganglionic commissure (*Comm.d.*) which connect the ganglion to the vagus with the first spinal ganglion. The motor roots of the spinal — occipital nerves are well developed, but are not connected with the ganglia (*G.sp.oc.*). The first fifteen spinal ganglia are represented in the reconstruction. They are all connected by the dorsal ganglionic commissure, although in a younger embro 15 mm. in length, which is represented in Fig. 13, this ganglionic commissure is broken down in the anterior part of the trunk region. The sympathetic ganglia (*Symp.*) are seen as small oblong or spherical masses lying on the mesial surface of the spinal nerves at the level of the dorsal aorta.

All six gill slits now open to the pharynx. The thyreoid (*Th.*) lies below the second slit and is connected with the floor of the pharynx only by a slender cord. The hypophysis (*Hyp.*) extends forward and covers the anterior part of the infundibulum. Its connection with the pharynx is somewhat constricted. The distal portion is expanded and divided by shallow grooves into an anterior and two lateral lobes. Posteriorly the pharynx is very abruptly constricted to form the oesophagus which is dilated in turn, forming the long cylindrical stomach (*St.*). The duodenum (*Duo.*) is bent downward at an angle of nearly 90^{0} to the stomach, and also somewhat to the left. A slight constriction marks the boundary between these two structures. The vitelline duct (*D.vit.*) now opens to the intestine almost entirely in the right side. There is a small diverticulum in the duct just before its entrance into the intestine. The pancreas (*Panc.*) is somewhat lobulated; a ventral and posterior portion which probably represents the head of the adult organ being particularly prominent. The liver (*L.*) is represented as sectioned in the median line. The gall bladder (*G.bl.*) lies ventral to the posterior portion of the liver and is covered on its ventral surface by a layer of peritoneum. It is connected by a short broad cystic duct with the dilated distal end of the ductus choledochus (*D.chol.*). This dilatation also receives four hepatic ducts, three of which are represented in the figure. The ductus choledochus joins the duodenum on the right side just anterior to the entrance of the vitelline duct. The Wolffian duct (*W.d.*) arises from the body cavity by a long shallow groove, from the anterior end of which project upward two small funnels, the remains

of the two anterior tubules of the pronephros (*Proneph.*). The anterior mesonephric tubule is not connected with the body cavity. The three following tubules are connected with the body cavity, and overlap the Wolffian duct laterally but are not connected with this structure. The remaining tubules (*Mes.t.*) shown in the figure are connected with both the coelom and Wolffian duct and possess two marked sacculations. They may be compared in their stage of development with those of an embryo of *Pristiurus* 17 mm. in length reconstructed by RABL and illustrated in Fig. 17 of Plate XVII, of his "Theorie des Mesoderms".

The pericardial cavity is now distinctly cut off from the coelom along the median line by the septum transversum (*S.trans.*). The heart needs no particular description. As stated above the branchial vessels are represented as cut off near their origin. The deep ophthalmic artery (*A.oph.*) is seen extending forward lateral to the hypophysis and dividing into two branches above the optic stalk. The vitelline artery (*A.vit.*) arises from the dorsal aorta by one trunk at the level of the septum transversum. The large veins passing into the sinus veinosus are in a similar stage of development to that described and figured for the embryo 15 mm. in length, except that the lateral vein (*V.lat.*) now enters the sinus venosus between the common cardinal and vitelline vein.

Fig. 16. Graphic reconstruction of an embryo 20.6 mm. in length. Normal plate series No. 28. (H.E.C. 1494.) × 15.

This is the last of the series of reconstructions of the general anatomy presented in this paper. The general method of representation of the various structures is similar to that employed in Fig. 12. The pharynx, however, is indicated only in outline, because any representation of the great expanded gill clefts would obscure other structures. The optic vesicle has been omitted for the same reason.

The reconstruction shows the great enlargement of the telencephalon vesicles (*Telen.*). The floor of the fore-brain is also directed somewhat upward anteriorly. The diencephalon is somewhat constricted at its cephalic end, and its roof is now almost entirely occupied by the well marked paraphysis (*Pa.*) and epiphysis (*Epi.*). The latter structure is decidedly dilated at its distal extremity. Although not distinctly indicated in the figure there is a slight subdivision of the diencephalon into parencephalon and syncephalon. The infundibulum (*Inf.*) is markedly enlarged and the well marked mammillary process is directed anteriorly. The mesencephalon (*Mesen.*) is markedly dilated and the rhombo-mesencephalic fissure (*F.r.-mes.*) now indents the lateral wall of the brain from dorsal to ventral surface. The anlage of the cerebellum is represented by a decided thickening of the roof of the hind-brain. The oculomotor nerve (*N.oc.*) extends backwards as far as the notochord. The trochlearis (*N.tr.*) is represented by a small filament arising from the dorsal surface of the brain in line with the rhombo-mesencephalic fissure. The trigeminal nerve (*N. trig.*) is somewhat obscured by the overgrowth of the ganglion of the facial nerve. Its ganglion is "Λ"-shaped in outline, and the mesocephalic ganglion (*G.mes.*) is decidedly enlarged. From the ganglionic bridge connecting these two structures there extends forward as small filament, the superficial ophthalmic ramus of the trigeminus (*R.oph.sup. V*). The deep ophthalmic ramus (*R.oph.pro. V*) extends downward a short distance beyond the mesocephalic ganglion. The ganglion of the facialis shows distinct division into three parts; the ganglia of the ramus ophthalmicus superficialis (*G.r.oph.sup. VII*), the ramus buccalis (*G.r.bucc. VII*) and the ramus hyoideus (*G.r.hyo. VII*). From the ventral surface of the last of these springs a small filament, the palatin ramus of the facial nerve. The acoustic ganglion covers a small portion of the ventral and lateral surfaces of the otocyst. The glossopharyngeal ganglion (*G.g-ph.*) is represented as cut off near its origin from its dorsal surface and a small nerve filament, the supra-temporal ramus (*R.s-t. IX*) extends upward along the external surface of the posterior canal pocket. The four branchial rami of the vagus (*G.br.X*) are represented as cut off near their origin. The lateral line ramus (*R.lat.X*) of the vagus extends backwards

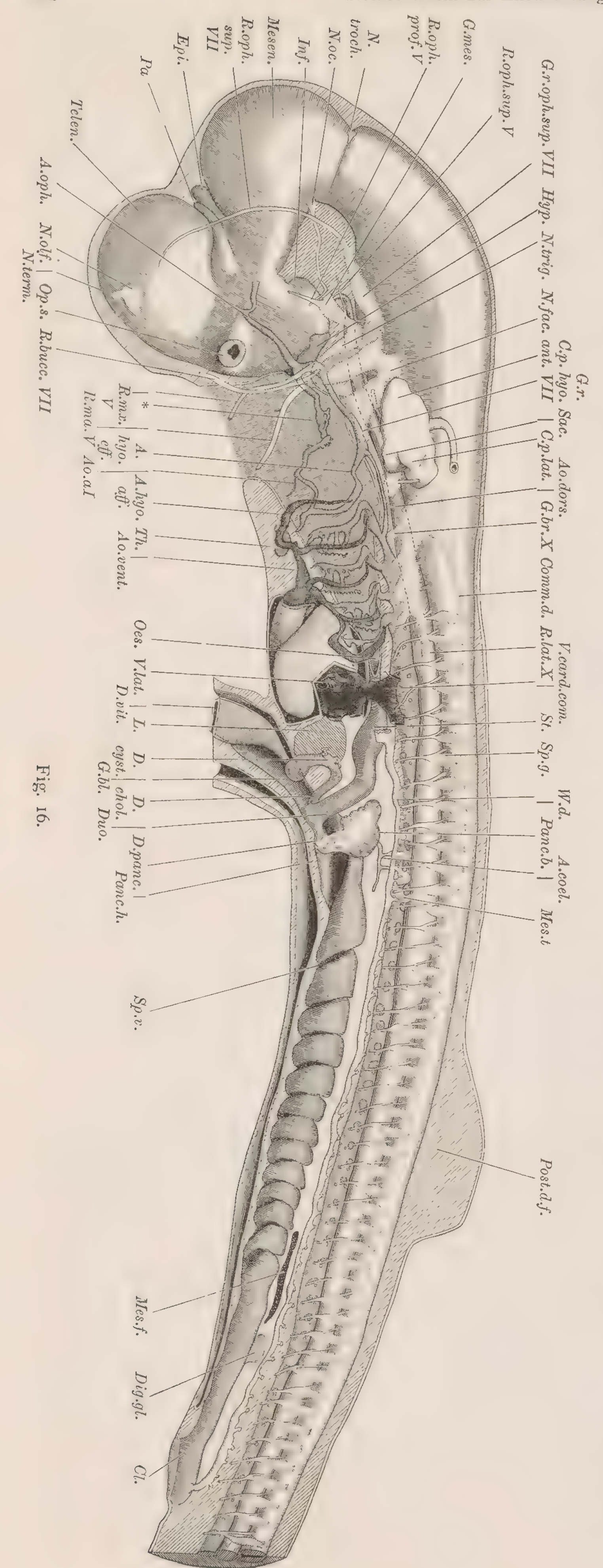


Fig. 16.

to the mid trunk region, but is represented in the figure as cut off between the second and third spinal ganglia. The dorsal ganglionic commissure (*Comm.d.*) is still continuous between the vagus and the first spinal nerve. Two slight enlargements of the commissure represent the first and second occipital ganglia respectively. The ventral roots of the spino-occipital are seen extending under the cover of the posterior part of the vagus ganglion. The first four spinal nerves are completely reconstructed; it will be noticed that the second, third and fourth extend backwards towards the base of the pectoral fin. In the trunk region the dorsal ganglionic commissure is now absent except between the thirty-second and thirty-third spinal ganglia (*Sp.g.*). The sympathetic ganglia (*Symp.*) are much enlarged and are present on all the spinal nerves. The eye is omitted from this reconstruction, but the optic stalk is shown in cross section (*Op.s.*). As in the preceding reconstruction the ventral wall of this structure is somewhat thickened, indicating the invasion of the optic fibers. The origin of the olfactory nerve is indicated in stipple upon the base of the lateral surface of the telencephalic vesicle (*N.olf.*). The terminal nerve, of Pinkus or Locy (*N.term.*) arises just mesial to the olfactory. The otocyst shows a considerable advance in development when compared with the condition of this structure in the preceding embryo, the anterior, lateral, and posterior canal pockets (*C.p.ant.; lat.; post.*) are distinctly outlined and the sacculus (*Sac.*) which was barely indicated in the otocyst of the 18 mm. embryo is now a well marked sack lying below the lateral canal pocket. The ductus endolymphaticus arises from the mesial wall of the otocyst.

As has been mentioned above the pharynx is only indicated in outline. From its anterior dorsal angle springs the hypophysis (*Hyp.*) now distinctly divided into an anterior expanded portion and a narrower posterior stalk. The anterior portion is in turn subdivided into one median and two lateral pouches. The anterior end of the oesophagus (*Oes.*) is much expanded transversely, but becomes reduced almost immediately into a tube which is almost circular in cross section. The stomach (*St.*) is somewhat dilated

and distinctly marked off from both the oesophagus and the duodenum. The duodenum (*Duo.*) is of large caliber, and is directed downward and backward at an angle of nearly forty-five degrees to the stomach. At its base it receives the ductus choledochus (*D.chol.*). The vitelline duct (*D.vit.*) now much reduced in size, enters the gut at the point of juncture of the duodenum with the intestine proper. The twisting process which forms the spiral valve has also produced a deep furrow on its posterior and ventral surface. The spiral valve (*Sp.v.*) makes thirteen complete turns. The segment of the gut lying immediately behind the spiral valve and anterior to the cloaca tapers gradually posteriorly. The cloaca (*Cl.*) receives the Wolffian ducts. Its floor is in contact along its entire extent with the anal plate of ectoderm. The liver (*L.*) has been represented in median section as in the reconstruction of the embryo of 18 mm. (Fig. 15). The gall bladder (*G.bl.*) now lies with its long axis almost in the dorso-ventral plane of the body. It is expanded distally, and constricted at its upper end to form a short broad cystic duct (*D.cyst.*). This structure opens into a small chamber, corresponding with the original median chamber of the liver, which receives also three hepatic ducts. From this median chamber the ductus choledochus (*D.chol.*) passes backward to the duodenum first bending upward and then downward in its course. The pancreas (*Panc.*) is now broadly expanded distally, and a large number of secondary pouches are given off from the walls of the original one. The large pancreatic duct (*D.panc.*) is represented by a ridge upon the lateral surface of the structure. The duct opens into the intestine on the ventral edge of its left surface just posterior to the duodenum. Near the entrance of the pancreatic duct is a small mass of pancreatic tissue which represents the head of the adult pancreas (*Panc.h.*). This is the first figure showing the rectal or digitiform gland (*Dig.gl.*). This structure arises from the right and dorsal surface of about the middle of the post-valvular portion of the gut, and extends a little forward. It is connected with the gut along almost its entire base. Anterior to the digitiform gland is a long narrow slit in the mesentery, the beginning of the mesenteral fenestra (*Mes.f.*). The Wolffian duct (*W.d.*) arises by a long coelomic funnel at the level of the sixth spinal nerve, and joins the cloaca near the dorsal median line and its posterior third. Thirty-seven mesonephric tubules are present, but only the anterior five are represented in the reconstruction, the others being indicated only by the ends of their distal portions where joining the Wolffian duct. The first three mesonephric tubules are rudimentary, the first two not being fused with the Wolffian duct. The fourth and fifth mesonephric tubules (*Mes.t.*) show the characteristic form of the series, and consist of a narrow anterior and a dilated posterior chamber, the latter communicating with the Wolffian duct by a constricted neck. These may be compared appropriately with those represented in Figure 20 of Plate XVII of Carl Rabl's "Theorie des Mesoderms".

The outlines of the heart are somewhat obscured by the overlapping blood vessels. The general antero-posterior shortening of the structure is, however, quite noticeable. The bulbus cordis is very much shortened and thickened and tapers down to a vessel of small caliber anteriorly. The formation of the efferent and afferent branchial vessels is now far advanced. In the reconstruction the afferent series of vessels is differentiated from the remaining arterial system by being represented in black crossed with white. The original ventral connection of the first aortic arch with the ventral aorta is now completely obliterated, but extremely small vascular cords represent the position of the connection. There is no indication of a thyreo-spiracular artery in this specimen. A broad and well established vessel now connects the hyoidean artery with the first aortic arch. Midway between this anastomosis and the sinus cephalicus the capillary system of the spiracular demibranch (*) is in the process of formation. The posterior part is already differentiated into short vascular loops the cut ends of which are seen in the figure. The anterior part is in a state of development comparable with that seen in the second and third arches in the embryo of 15 mm. (Figs. 13, 14). The afferent artery of the hyoid arch is completely separated from the efferent

vessel (*A.eff.hyo.*) except for a large number of capillary loops which extend into the gill filaments. For the sake of clearness these have been omitted in the figure. The third and fourth aortic arches present characteristic stages in the differentiation of these structures and may be described together. The third the afferent artery still possesses dorsal and ventral communications with the efferent vessel, but these communications are very much reduced in size and their lumina are almost occluded. The efferent artery is divided into a posterior and anterior limb. These two vessels are connected by three large irregular vascular channels which lie mesial to the afferent vessel. The stubs of the vascular loops of these demibranchs have been represented in outline. The efferent portion of the fourth aortic arch is similar to that of the third with the exception that the ventral communication with the afferent vessel is represented only by a short sprig in which the lumen is occluded, and that there are two instead of three communications between the anterior and posterior portions of the afferent artery. The fifth aortic arch represents a somewhat earlier stage in the development of the branchial arterial system. Both the afferent and efferent vessels form complete connections with the ventral and dorsal trunks of the arch although the dorsal connection of the afferent vessel is considerably reduced in size. The afferent portion is divided into anterior and posterior sections after the same manner described for the two preceding arches. The afferent portion of the sixth arch has retained its original size throughout and is complete. The efferent portion is represented by a vessel springing from the dorsal end of the arch extending ventrally anterior to the afferent portion and communicating with the ventral root by a very small channel. From this afferent portion there extend posteriorly, mesial to the efferent trunk, several irregular sprouts which are doubtless destined to form the last branchial artery. That section of the dorsal aorta lying between the second and third arches is much reduced in caliber, and the connection between the first arch and the dorsal aorta, i. e., the sinus cephalicus, is somewhat obscured in the figure by the overlapping nerves. It is very much enlarged and from it the ophthalmic artery (*A.oph.*) extends forward mesial to the optic cup. The first of the visceral arteries, the coeliac artery (*A.coel.*), is now established. It arises by two segmentally placed branches from the aorta just posterior to the pancreas and extends a short distance both forward and backward in the mesentery.

From the sinus venosus there spring three sets of vessels. Dorsally there extends a short thick common cardinal (*V.card.com.*) which divides almost immediately into the anterior and posterior cardinals. The lateral vein (*V.lat.*) opens below the common cardinal vein. The opening on the anterior surface of the lateral vein is that of the jugular vein.

Fig. 17. Graphic reconstruction of the head somites of an embryo 4 mm. in length. Normal plate series No. 16. (H.E.C. 430.) × 33.

The general method of representation which has been employed in this figure is the same as that used particularly for the mesodermic structures in Fig. 6. The embryo is represented as sectioned transversely a little behind the anterior wall of the yolk stalk. The general description of structures other than the mesoderm is given in connection with the description of Fig. 7 which is another reconstruction of the same embryo. The mandibular somite (*So.mand.*) consists of a large distal chamber extending forward above the eye and lying lateral to the pharynx and mid-brain. It is connected with the general lateral mesoderm by a short broad stalk. The small premandibular somite (*So.prem.*) lies mesial to the ventral portion of the mandibular somite. It is connected anteriorly by a short broad stalk with the anterior somite (*So.ant.*). This body is definitely formed and possesses epithelial walls dorsally, but it is mesenchymous ventrally,

and it has been found impossible to determine the exact boundary between its anterior wall and the mesectoderm of the thalamic nerve crest. The approximate boundary of the two structures is indicated by a dotted line. The hyoid somite (*So.hyo.*) lies above the dorsal margin of the distal expansion of the mandibular somite. It is still broadly connected with the lateral mesoderm posteriorly, and with a short broad stalk which passes downward and unites with the stalk of the mandibular somite at the base of the hyoid arch. No definite pericardial cavity has been established at this stage, but it will be noticed that the ventral portions of the lateral plate of mesoderm (*Pc.w.*) are extended laterally on either side of the anterior intestinal portal. Between the inner surface of this portion of the lateral mesoderm, and the lateral walls of the digestive tube is found an irregular and broken cord of angioblastic cells, — the anlage of the endothelial heart.

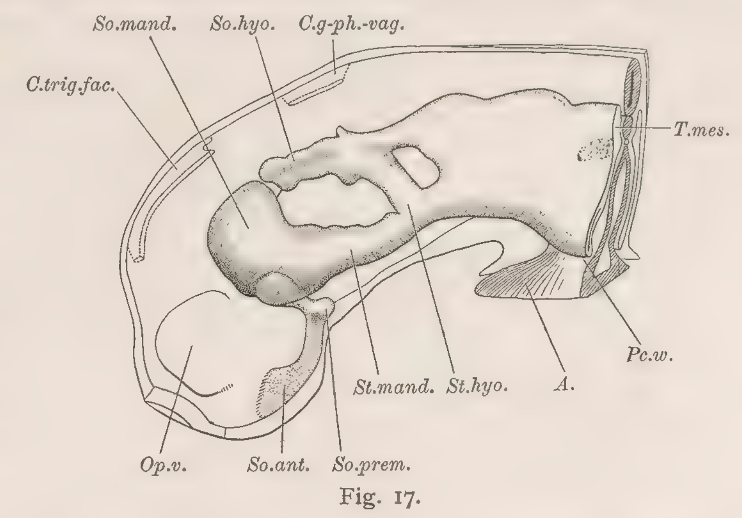


Fig. 17.

Fig. 18. Graphic reconstruction of the head cavity of an embryo 4.8 mm. in length. Normal plate series No. 18. (H.E.C. 1398.) $\times$ 33.

For general anatomy this reconstruction may be compared with Fig. 8, a reconstruction illustrating the general anatomy of the same embryo. The mandibular somite (*So.mand.*) now lies somewhat more anteriorly and dorsally in relation to the brain than it did in the preceding reconstruction. Its stalk is somewhat longer and its ventral and posterior part is curved slightly downward; a change due to the rapid growth of the first gill arch. Only the dorsal portion of the premandibular somite (*So.prem.*) now lies mesial to the mandibular. The anterior somite (*So.ant.*) is now completely separated from the premandibular somite, although it is nearly in contact with that structure. It lies entirely anterior to the premandibular, as well as the mandibular, somite. Anteriorly and ventrally it becomes indistinguishable from the mesectoderm of this region, in the same manner as in the embryo of 4.0 mm. The hyoid somite (*So.hyo.*) now lies mainly above and a little anterior to the first gill plate. Although broadly connected with the mesoderm of the second gill arch, a slight constriction in its ventral border indicates the point at which it will later separate from this mass.

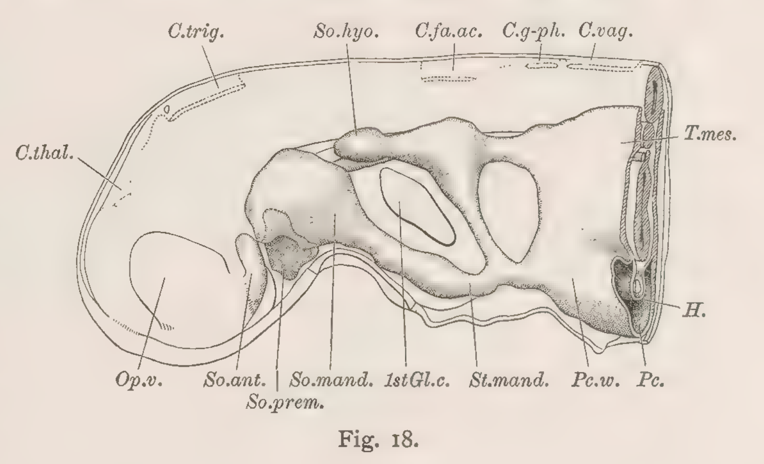


Fig. 18.

Fig. 19. Graphic reconstruction of the head somites of an embryo 5.2 mm. in length. Normal plate series No. 20. (H.E.C. 1352.) $\times$ 33.

This is a reconstruction of the same embryo as that represented in Fig. 9. The elongation of the pharyngeal region and general growth of the head has continued the changes in position of the somites

which are illustrated in preceding reconstructions. The stalk of the mandibular somite (*So.mand.*) is still more elongated as compared with the expanded distal extremity. The distal half of the premandibular somite (*So.prem.*) lies mesial to the mandibular somite. The premandibular somite is also elongating antero-posteriorly and its posterior extremity now extends into the upper part of the first gill arch. The posterior edge of the anterior somite (*So.ant.*) is now slightly overlapped by the anterior part of the pre-mandibular. All the walls of the anterior somite are now definitely outlined in meso-thelium. The somite has shifted in position until its long axis lies almost exactly in the transverse plane of the body.

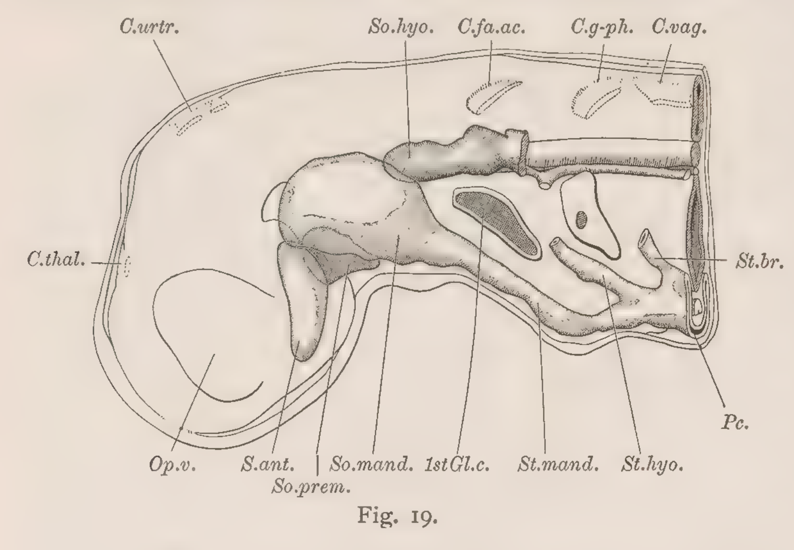


Fig. 19.

Fig. 20. Reconstruction of the head somites of an embryo 9 mm. in length. Normal plate series No. 23. (H.E.C. 1495.) × 33.

This figure represents the head cavities of an embryo already shown in reconstruction in Fig. 11. The mandibular somite (*So.mand.*) is very much elongated and is attached by a stalk nearly four times as long as the somite itself, to the anterior end of the pericardium. The premandibular somite (*So.prem.*) is lenticular in cross section, and is covered anteriorly by the mandibular and anterior somites. The anterior somite is crescenteric in outline, and lies in a small space between the optic vesicle below and the mandibular somite above. Its anterior portion lies almost exactly in the antero-posterior plane of the body. The hyoid somite (*So.hyo.*), which is completely separated from its stalk, overlaps the mandibular somite a little dorsally. The stalk of the hyoid somite (*St.hyo.*) extends upward from the pericardium, from which it originates in company with the stalk of the mandibular somite, to the top of the hyoid arch. Its dorsal end is mesenchymous. The first, second and third branchial somites have not been represented in the reconstruction, but their stalks which are in the main mesenchymous, are indicated as cut off close to their connection with the pericardium. The general anatomy of the embryo is described in connection with Fig. 11.

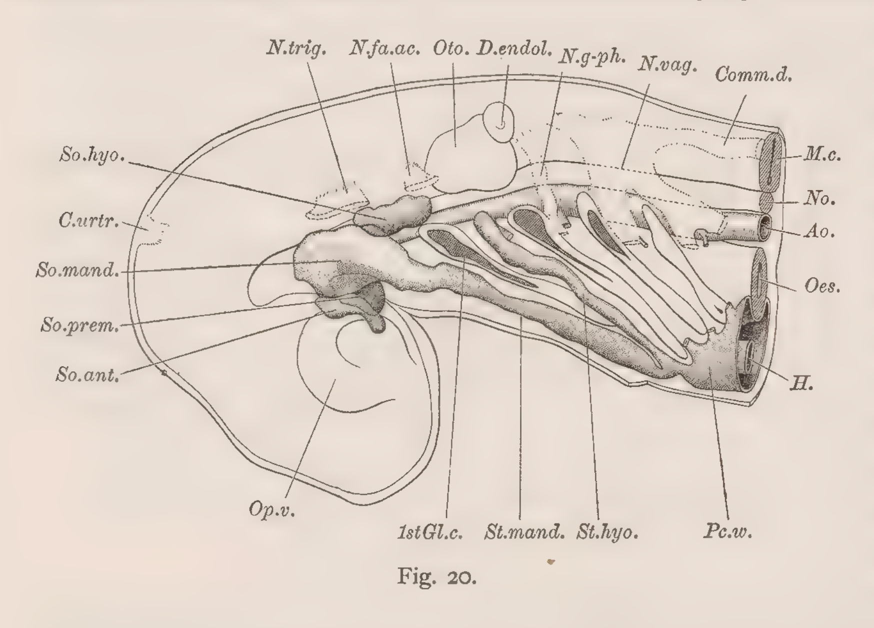


Fig. 20.

Fig. 21. Dissection of an embryo of *Squalus acanthias*, 15 mm. in length, corresponding to normal plate series No. 26. × 6.

The following is the first of a series of dissections illustrating the general appearance of the viscera of a series of embryos carefully correlated with certain stages of the normal plate series. The ventral body-

wall has been removed and the dissection has been carried forward to the base of the mandibular arches. The thyreoid gland (*Th.*) is a small tongue-like body, the base of which is attached to the pharynx. The heart still possesses its primitive "S"-shape, and in the view presented only the ventricle and bulbus cordis are seen, these structures obscuring the dorsally placed atrium. Although the septum transversum is formed along the median line at this stage, it is obscured in this view by the overlapping liver. The liver (*L.*) consists of two lateral lobes and an anterior median and connecting portion. The right lobe is somewhat larger than the left. The vitelline duct opens slightly to the right side into a somewhat dilated portion of the gut. To the left of the vitelline duct is seen the projecting ventral edge of the pancreas (*Panc.*). The spiral valve (*Sp.v.*) makes eight turns. The great obliquity of the upper turns as compared with the lower is noticeable. The gut narrows rapidly behind the last turn of the spiral valve, as it approaches the cloaca. The cloacal plate (*Cl.p.*) is elongately heart-shaped in outline and its central portion is slightly depressed.

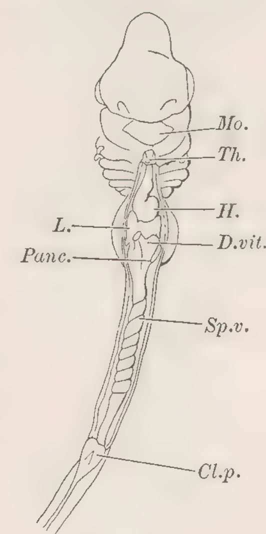


Fig. 21.

Fig. 22. Dissection of an embryo 18 mm. in length, corresponding with normal plate series No. 27. × 6.

The plan of this dissection is the same as that shown in the preceding figure. The thyreoid (*Th.*) is now attached to the pharynx by a slender anterior stalk. The bulbus cordis (*B.cor.*) is somewhat dilated as compared with the same structure in the preceding figure and the ventricle is a little narrower and longer. The somewhat dilated atrium (*At.*) is seen below the anterior edge of the ventricle. The right, left and median lobes of the liver are similar to those of the preceding dissection, and in this specimen also the right lobe is somewhat larger than the left. The vitelline duct is cut off somewhat closer to the intestine in this dissection than in the preceding one. The projecting ventral edge of the pancreas (*Panc.*) is again seen to the left of the vitelline duct. There are eleven turns of the spiral valve (*Sp.v.*). Dorsally and to the right of the gut immediately behind the last turn of the spiral valve there projects a small pouch, the anlage of the digitiform or rectal gland (*Dig.gl.*). The cloacal plate (*Cl.p.*) is now bounded by a pair of rounded arches which meet in front but are separated posteriorly by a narrow cleft.

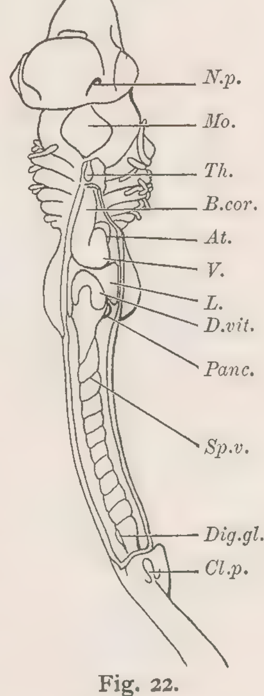


Fig. 22.

Fig. 23. Dissection of an embryo 21.0 mm. in length, corresponding to normal plate series No. 27. × 6.

In this embryo the lateral and ventral chambers of the nasal pits are sharply marked off, and the beginning of the canalis medialis (*Cn.m.*) of the lateral line system is just visable. The mouth is broadly oval in outline and slender gill filaments project from all of the gill slits. No attempt has been made to expose the thyreoid in this dissection. The heart is somewhat shorter and broader than in the preceding stages. The bulbus cordis (*B.cor.*) shows a marked bulging which is characteristic of

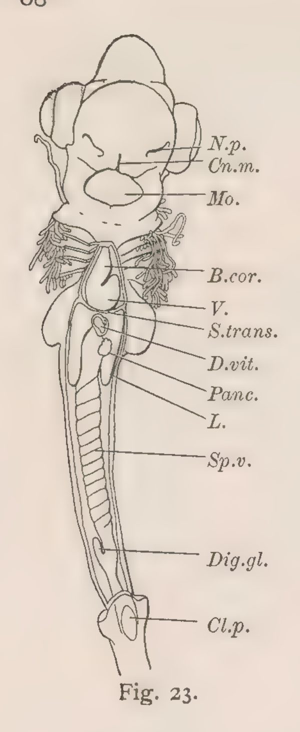


Fig. 23.

embryos from this time forward until they attain the length of over 30 mm. The atrium is completely obscured by the bulbus and ventricle (*V.*). The septum transversum (*S.trans.*) reaches completely across from side to side of the body cavity. The right and left lobes of the liver (*L.*) are now of almost equal size and extend posteriorly to the first turn of the spiral valve. The median or connecting lobe of the liver is somewhat broader than indicated in the figure, as it is obscured in part by the vitelline duct (*D.vit.*). Below and to the left of the vitelline duct is the ventral portion of the pancreas, which now lies in a notch in the left lobe of the liver, and which shows slight secondary lobulations. The spiral valve (*Sp.v.*) makes thirteen turns. The digitiform gland (*Dig.gl.*) is a prominent finger-like process extending forward from the right side of the gut near its dorsal surface. Immediately behind the digitiform gland the intestine is somewhat constricted. The cloacal plate now appears as an oval depression bounded on either side by low rounded ridges.

Fig. 24. Dissection of an embryo 28 mm. in length corresponding with normal plate series No. 29. $\times$ 6.

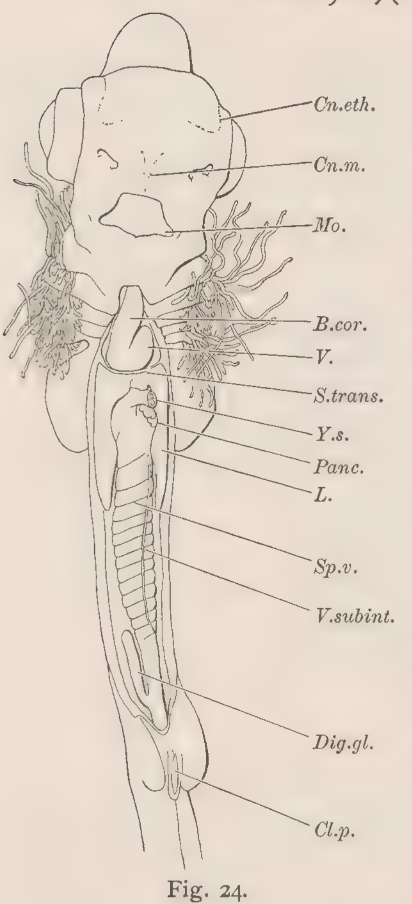


Fig. 24.

In this embryo the nasal flaps are beginning to develop. The median, ethmoid and pre-oral canals (*Cn.m., Cn.eth., Cn.pre.-o.*) are visiable, and long gill filaments project from all of the gill slits. The heart is similar in shape to that of the preceding dissection. The lateral lobes of the liver now extend posteriorly to the third turn of the spiral valve, and the inequality in size which characterized these structures in the younger embryos is now absent. Anterior to the vitelline duct, which is turned somewhat backward in the dissection, is seen a small projection which extends posteriorly from the connecting median portion of the liver. Posteriorly and to the left of the vitelline duct is the duct and ventral lobe or head of the pancreas (*Panc.*). Fourteen turns of the spiral valve (*Sp.v.*) are present, the adult number now having been attained. The great diameter of the middle portion of the intestine as compared with its posterior and anterior extremities is noticeable in this embryo, and is characteristic of this and succeeding stages. The subintestinal vein (*V.sub-int.*) extends along the ventral surface of the intestine, slightly to the left of the median line. The digitiform gland (*Dig.gl.*) now arises far posterior to the last turn of the spiral valve. It is much elongated, and lies completely on the right side of the intestine. The cloacal plate (*Cl.p.*) which is seen in part in side view, differs but little from that seen in the preceding dissection.

Fig. 25. Dissection of an embryo 34 mm. in length, corresponding to normal plate series No. 31. $\times$ 6.

In this embryo the lateral and mesial chambers of the nasal pits (*N.p.*) are almost separated externally by the nasal valves. There is a distinct ventral border to the rostral plate (*R.pl.*) and the ethmoid (*Cn.eth.*),

infra-orbital (*Cn.inf.-or.*), hyoid (*Cn.hyo.*), infra-rostral (*Cn.inf.-ros.*) and medial (*Cn.m.*) canals are present. Long gill filaments project from all of the gill slits. The heart shows a marked dilatation of the bulbus cordis (*B.cor.*) already mentioned as characteristic of embryos of about this stage. The lateral lobes of the liver (*L.*) are now enormously increased in size, and extend backward to the sixth turn of the spiral valve. A small tongue-like projection from the median lobe overlaps the right side of the base of the vitelline duct. The ventral lobe or head of the pancreas (*Panc.*) and the pancreatic duct are seen on the left side of the intestine above the first turn of the spiral valve. The spiral valve (*Sp.v.*) makes fourteen complete turns. As compared with the preceding embryo the greatly increased breadth of the intestine is noticeable. Between the last turns of the spiral valve and origin of the digitiform gland the intestine is much constricted. (See normal tables, p. 37.) Again behind the point of origin of the digitiform gland (*Dig.gl.*) the intestine passes into a constricted portion which in turn leads into the cloaca. The cloacal plate (*Cl.p.*) is lenticular in outline and is bounded by rounded arches, the beginning of the claspers.

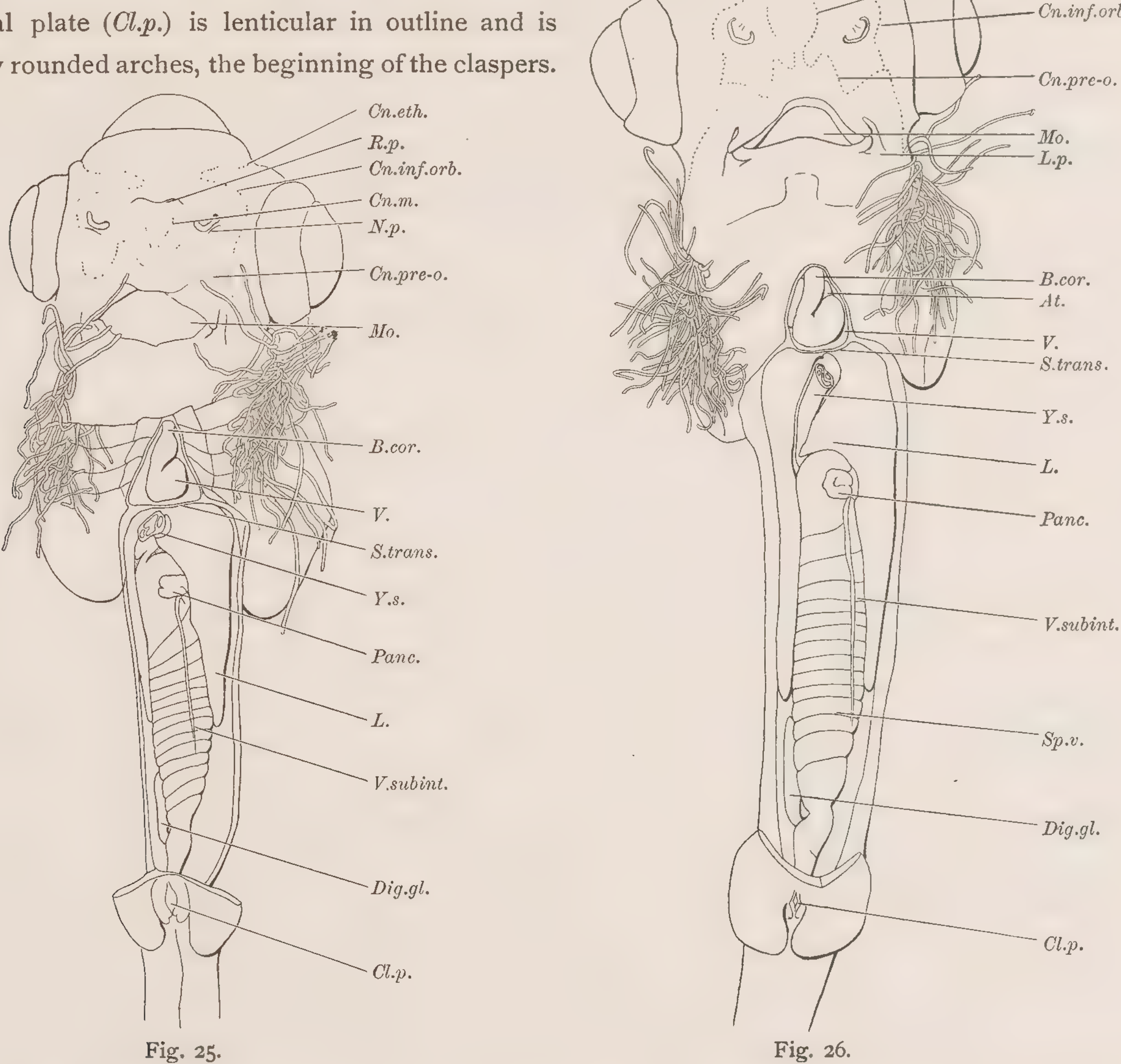


Fig. 25. Fig. 26.

Fig. 26. Dissection of an embryo 37 mm. in length, corresponding to normal plate series No. 32. × 6.

In this embryo nasal flaps are completely formed, and the lateral line system somewhat further developed than in the embryo of the preceding dissection. The labial pockets (*L.p.*) well established. The gill filaments are in about the same stage of development as in the preceding dissection. The pericardial cavity is now reduced in size as compared to the preceding dissection. The bulbus cordis (*B.cor.*) is

cylindrical, and is separated anteriorly from the ventricle by a slight constriction. Above the anterior portion of the ventricle and bulbus cordis is seen the dilated atrium (*At.*). The liver (*L.*) now extends posteriorly to the tenth turn of the spiral valve. The right and left lobes are of almost equal size, and the median mass which apparently arises from the left lobe is much increased in size as compared with the preceding dissection. The yolk stalk (*Y.s.*) lies in a notch between the median and the right lobe. In its cut end are seen in cross section the vitelline duct, the vitelline artery and the vitelline vein. The ventral lobe or head pancreas (*Panc.*) and the pancreatic duct have the same position as that occupied in preceding dissections. The sub-intestinal vein (*V.sub-int.*) forms a prominent ridge extending from the pancreas backward nearly to the last turn of the intestine. The intestine is decidedly constricted anterior to the digitiform gland. This is associated with changes in structure which are described in the tables on page 37. The digitiform gland (*Dig.gl.*) now lies posterior to the intestine. The cloacal plate (*Cl.p.*) is diamond-shaped in outline and bounded by a pair of low rounded folds.

A comparison of the members of the normal plate series with some stages established by other authors.

The literature of elasmobranch embryology contains a number of important contributions in which the embryonic period is considered as divided into a series of stages or phases. Broadly speaking these contributions may be separated into two classes. First, those containing descriptions of certain individual specimens which are considered as norms by which the position of other specimens, in relation to their development, may be determined. Such "norms" have generally received some symbol such as a letter or number, and this symbol also designates the stage they represent. A second class contains papers presenting divisions of the embryonic period based upon general characters of external form or internal structure. Any division into formal stages of a period of gradual change and differentiation is perhaps open to criticism as being arbitrary and artificial. The stages established by the method of the first class of contributions mentioned above have the advantage of precision. They are applicable however only to the species they represent or to closely related forms. In avoiding this disadvantage the stages presented in contributions of the second class are generally characterized in terms so general that the exact placing of any embryo is often very difficult.

Artificial as the device of formal stages may be it has proved sufficiently useful to become thoroughly incorporated in the literature of elasmobranch development, and it has been thought desirable to attempt to correlate the series of embryos described in the preceding pages with some of the well known series and stages of other authors. The results of this attempt are embodied in a general correlation table which is to be found on p. 72 of this paper. To make this table more intelligible there follow below brief reviews of the contributions which have been so tabulated. As the stages presented in the classic work of Balfour are so frequently referred to in elasmobranch work they are considered in some detail, and when an author has correlated his series with this well known one I have given the correlation in tabular form.

In addition to these papers there are included in the table and the discussion several contributions in which no attempt is made to present formal stages but which contain descriptions of at least part of the anatomy and sometimes of the external appearance of series of elasmobranch embryos. Most of these papers deal with *Squalus acanthias.*

Although several series of elasmobranch embryos were figured and partially described[1]) prior to the Leydig's contribution, with which this table begins, the data presented by them seemed to meager to admit of a correlation of value. The second part of Leydig's Beiträge zur mikroskopischen Anatomie und Entwicklungsgeschichte der Rochen und Haie[2]) (Table IX, column 2) contains an account of the egg and segmentation of *Pristiurus* and a description of a series of four embryos of *Squalus acanthias* of 7''', 1'', 2'' and 3'' respectively. The youngest embryo of the series is described in detail, the account including a description of the viscera, notochord, vascular system, brain and gill slits. A figure of this specimen seen as a transparent object is included in the plates. The external anatomy of the remaining members of the series is figured and there is a general account of the development of the notochord, gill slits, lateral line, urogenital system and skull.

His[3]) in 1876 (Table IX, column 3) published a careful study of a number of young embryos of *Pristiurus* and *Scyllium.* The series consists of twelve stages representing the development from a slight thickening of the posterior rim of the blastoderm to a period when only the middle two-fifths of the embryo is attached to the blastoderm and twenty-seven pairs of segments and three gill slits are present. Eight of the twelve stages are illustrated by excellent figures, the magnification of which is given in connection with the plate. A very complete set of measurements of the embryos after fixation is included in the paper. In a second contribution which appeared in 1894 His has correlated this series of embryos with Balfour's stages[4]).

The "stages" (Table VIII, column 4) established by Balfour have become so incorporated in the literature of elasmobranch embryology that they are considered here in some detail. A section of Balfour's work upon the embryology of elasmobranch fishes[5]) contains figures and descriptions of a series of some seventeen embryos, ranging in development from the segmented blastoderm to a stage when "the head resembles that of an adult fish". These stages the author designated by a series of letters "A" to "Q" inclusive, there being no stage "J", and throughout the remainder of the work the statement of the "stage" is used to indicate the general state of development of the embryo. This series is made up of several species of elasmobranchs. Stages "A", "B", "C", "D", "E", "F", "H", "I" and "K" are represented by embryos of the sawfish *Pristiurus*; "G" by *Torpedo*; "L", "M", "N", "O", "P" and "Q" by the European dog fish *Scyllium canicula.* The mode of preparation of the figured specimens in also not always the same. The figure of stage "B" represents a fresh unfixed blastoderm. "G", "H" and "I" are figures of embryos "viewed as transparent objects" and also represent living specimens; the remaining figures are of embryos fixed in chronic acid. The figures of "A" to "F" inclusive are dorsal views; "G", "H" and "I" are lateral views of transparent specimens; "K", "L", "N" and "O" are seen in lateral view, and the ventral surface of the head and pharyngeal region of each of these specimens is shown in a separate drawing on a larger scale. Only the head and pharyngeal region, as seen in lateral view, is figured for stages "M", "P" and "Q". No scale of magnification is given in Balfour's work, but a study of the figures shows that it has been changed at least three times in the course of the series.

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1) Among these may be mentioned:
1834 Davy, J., Observations on the Torpedo. Trans. Roy. Phil. Soc. London, p 531—550.
1867 Wyman, S., Observations on Raia batis. Mem. Amer. Acad., Vol. 9, 1867, p. 31—44, 1 pl.
1850 Leuckart, R., Ueber die allmähliche Bildung der Körpergestalt bei den Rochen. Zeitschr. f. wiss. Zool., Bd. 2, p. 254—267, Taf. XIV.

2) F. Leydig, Beiträge zur mikroskopischen Anatomie und Entwicklungsgeschichte der Rochen und Haie, 127 pp., 4 Taf., 8⁰, Leipzig 1852.

3) W. His, Ueber die Bildung der Haifischembryonen. Zeitschr. f. Anat. u. Entw., Bd. 2, p. 108—124, Taf. VII.

4) See review of this paper on p. 73.

5) F. M. Balfour, The development of elasmobranch fishes. From B to G. Journ. Anat. and Phys., Vol. 10, p. 672, 688, Plate XXIX.

Two considerable gaps occur in BALFOUR's series as figured. The period between stage "F" with the medullary groove widely open anteriorly, the cephalic plate widely expanded, and the incisura neurentica still in evidence, and "G", in which the medullary canal is completely closed and the neck bend well established, corresponds to the largest gap. Stages "I" and "K" (there is no "J") are also far removed. In the former the relation on the antero-posterior diameter of the yolk stalk to the length of the embryo is as one to four. In the latter the same relation is as one to seven. During the period which has intervened between these two stages the entire contour of the body has changed. The head is much more flexed and is increased in size. BALFOUR states that embryo "L" is nearly twice as long as "K", but considers that part of this difference in length is due to the fact that they are embryos of different species and genera and that the embryos of *Scyllium*, of which "L" is one, are larger in proportion to the stage of development than are those of *Pristiurus*, of which "K" is an example. Embryos "E" and "F" are considered by BALFOUR as representing one stage. '"E" appears a little abnormal in not having a cephalic region as distinctly marked off from the trunk as usual.' The figures of BALFOUR's series have been at least three times republished[1]) and two sets of embryos matched to the younger members of BALFOUR's series have been figured and described[2]).

KASTSCHENKO[3]) (Table IX, column 5) in 1888 in a preliminary contribution on the early development of Selachians presented a classification of the "stages of development up to the time when the medullary canal is completely closed". No figures are included but the duration in days of several of the stages as observed at the aquarium at Naples is given in some instances. KASTSCHENKO's classification, together with his correlation of his stages with those of BALFOUR, is given below in tabular form.

Table I.

Tabulation of KASTSCHENKO's stages of *Pristiurus melanopus*, *Scyllium catulus*, *S. canicula*, together with their duration in time and their correlation with the stages of BALFOUR.

KASTSCHENKO's stages					BALFOUR's stages
No.	Title of stages	Duration of stages in days			
		A*)	B	C	
I	Befruchtete, aber unsegmentierte Keimscheibe	—	—	—	—
II	Oberflächliche Segmentation	2	—	—	—
III	Tiefe Segmentation	4	3—4	—	—
IV	Stadium der von außen sichtbaren Segmentationshöhle	6—7	10—11	11	—
V	Rüsselförmige Keimscheibe	2—3	4	4	A
VI	Sattelförmige Keimscheibe	3—5	4	5	—
VII	Lanzettenförmiger Embryo	2	2	—	B
VIII	Knopfförmiger Embryo	1—2	2	—	D
IX	Stadium der Medullarplatte	1	—	—	—
X	Stadium der Medullarrinne	3	—	—	—
XI	Stadium des eben geschlossenen Medullarrohres	2—3	—	—	—

*) A *Pristiurus melanopus*, B *Scyllium catulus*, C *Scyllium canicula*.

1) a) 1896, B. DEAN, Fishes, recent and fossil. Vol. III. Columbia University Biological Series, Figs. 216—228, 284—289. (A figure of a large foetus of *Squalus acanthias* has been added to the series.) — b) 1902, F. KEIBEL, Die Entwicklung der äußeren Körperform der Wirbeltierembryonen in HERTWIGs Handbuch der vergl. u. exp. Entw. d. Wirbeltiere, Bd. 1, Teil 2, Fig. 5, p. 15—22. — c) 1902, H. E. ZIEGLER, Lehrbuch der vergleichenden Entwicklungsgeschichte der niederen Wirbeltiere, Fig. 72, p. 102—105. (Figures of stages "B, C, E, H, M, P, Q" omitted.)

2) a) 1892, H. E. ZIEGLER und F. ZIEGLER, Beiträge zur Entwicklungsgeschichte von *Torpedo*. Arch. f. mikr. Anat., Bd. 39, p. 56—102, Taf. III—IV. — b) 1894, W. HIS, Sonderung und Charakteristik der Entwicklungsstufen junger Selachierembryonen. Arch. f. Anat. u. Phys., Anat. Abt., p. 337—354, Taf. XXI.

3) 1888, N. KASTSCHENKO, Zur Entwicklungsgeschichte des Selachierembryos. Anat. Anz., Bd. 3, p. 445—467.

In 1892 H. E. Ziegler and F. Ziegler[1]) published an account of a series of embryos of *Torpedo ocellata* selected to correspond with Balfour's stages "B", "C", "D", "E", "F", "G", "H" and an intermediate stage between "I" and "K". (Table IX, column 6.) The well-known wax models of *Torpedo* from the atelier of F. Ziegler are based upon a careful study of fresh specimens and photomicrographs of "B", "C", "D", "E—F" and "I—K" of this series. Besides photographic reproductions of these models the paper includes figures and descriptions of cross sections of the various stages. "H" and "I—K" are also figured as cleared specimens corresponding to Balfour's figures of these stages. From a comparison of Balfour's and Ziegler's figures it would seem that the correlation is not a very exact one. "Stadium B" appears when compared with Balfour's plate to lie between "Stage B" and "Stage C". Ziegler's "Stadium C" likewise is farther advanced than Balfour's stage of that letter and probably lies between Balfour's "C" and "D". "Stadium D" is comparable to Balfour's "E", for the medullary folds are well raised both anteriorly and posteriorly. Ziegler's "F" is wholly unlike the embryo of the same letter figured by Balfour, in which the cephalic plate is widely expanded and the caudal folds far separated. Ziegler's figure is of an embryo with the anterior half of the medullary canal completely closed, the eye forming a prominent lateral swelling, one distinct gill pouch, and fifteen segments visible externally; it corresponds very well to Balfour's "G", an embryo with seventeen segments. The author remarks that "F", which is represented by an embryo of *Pristiurus* in Balfour's series, is not well-marked in *Torpedo*. "Stadium G" is but little older than "Stadium F", and probably should be placed between "G" and "H".

His[2]) (Table IX, column 7, A and B) in 1894 contributed a second paper on the early development of elasmobranchs. He adopted Balfour's nomenclature of stages and gave a table, which is reproduced below, correlating the stages described in his earlier contribution with those established by Balfour.

Table II.

Tabulation of His' correlation of a series of embryos of *Pristiurus* and *Scyllium* with Balfour's stages.

His' series		Balfour's stages
Embryo	Length	
XXXIX	0.25 mm.	A
XXXVII	0.75 „	B
XX	1.4 „	C
I	1.8 „	D
XXI	2.75 „	E—F
XVI	2.65 „	G

His also figures a series of nine embryos of *Pristiurus*, giving with them a table of measurements taken from the specimens when mounted in balsam. The general body development of the period covered by these stages is briefly described. In the normal plate correlation table this series has been placed under the sub-head "A" of the column given to this paper. His' table of measurements of the *Pristiurus* series and his correlation of its members with the Balfour series is given in the following table.

1) H. E. Ziegler and F. Ziegler, loc. cit. — Ziegler's illustrations have been at least twice reproduced: 1902, F. Keibel, loc. cit. Fig. 6; 1902, H. E. Ziegler, loc. cit. Figs. 86, 88, 92, 97, 105.

2) W. His, Sonderung und Charakteristik der Entwicklungsstufen junger Selachierembryonen. Arch. f. Anat. u. Phys., Anat. Abt., p. 337—354, Taf. XXI, 18 figs.

Table III.

Tabulation of HIS' correlation of a series of *Pristiurus* embryos with BALFOUR's stages and of a set of measurements of the former.

His' series					Balfour's stages
No.	Länge des Hufeisens	Breite des Hufeisens	Breite des Vorderkopfes	Breite des Hufeisenstreifens, vorn gemessen	
1	0.4 mm.	0.55 mm.	—	—	B
2	0.55 „	0.65 „	—	0.25 mm.	B
3	0.7 „	0.7 „	—	0.28 „	B
4	0.8 „	0.7 „	—	0.28 „	B
5	1.0 „	0.65 „	0.62 mm.	0.28 „	C
6	1.15 „	0.55 „	0.62 „	—	C
7	1.14 „	0.33 „	0.75 „	—	D
8	1.6 „	0.33 „	0.75 „	—	D
9	2.0 „	0.33 „	0.75 „	—	E

A second part of the same paper contains descriptions and reconstructions, plastic and graphic, of embryos corresponding to BALFOUR's stages "C", "D", beginning of "E", end of "E" and "F". These have been placed under "B" in the column devoted to this paper in the normal plate table. The stages reconstructed by HIS concur closely with those of BALFOUR bearing the same designation, with the exception of "F". Of this he says: "Zur Stufe "F" rechne ich gleich den Gebr. ZIEGLER solche Embryonen, bei denen das Markrohr schon großenteils geschlossen ist . . ." The embryo reconstructed is one of *Scyllium canicula*, of 13 or more segments, and seems to be more comparable with BALFOUR's "G".

EMMERT, in 1900[1]) (Table IX, column 11), published an account of four young embryos of *Torpedo marmorata*. The anatomy of each specimen is briefly described and is illustrated by cross sections. In addition to the account of the general anatomy there is a more detailed description. The external appearance of the series is illustrated by photogravures of each specimen as seen from above. The author carefully correlates his specimens with the ZIEGLER's modification of the BALFOUR series. This correlation is presented below in tabular form.

Table IV.

Tabulation of EMMERT's correlation of his series of embryos of *Torpedo marmorata* with the "BALFOUR-ZIEGLER" stages.

Emmert's series			"Balfour-Ziegler" stages
Stadium	Length	Number of segments	
I	2.3 mm.	10	D
II	—	12	F
III	3.2 mm.	16	F—G
IV	—	—	H

Besides the LEYDIG's contribution, which has already been considered, four other papers dealing exclusively with *Squalus acanthias* have been tabulated.

LOCY's preliminary paper[2]) upon the medullary plate and groove (Table IX, column 8), contains brief discussions of a number of the main characters of early embryos of *Squalus*. The period covered

1) J. EMMERT (1900), Beiträge zur Entwicklungsgeschichte der Selachier, insbesondere nach Untersuchungen an jüngeren Embryonen von *Torpedo marmorata*. Arch. f. mikr. Anat., Bd. 56, p. 459—487, 38 figs., Taf. XX.

2) W. A. LOCY (1893), The formation of the medullary groove and some other features of embryonic development in elasmobranchs. Journ. Morph., Vol. 8, p. 367—378, pl. XIX.

is from a stage between BALFOUR's "A" and "B" to and including BALFOUR's "F". (N.P.S. No. 3 to N.P.S. No. 15.) The development of the medullary plate and groove is illustrated in a series of external views and transverse sections. No measurements of the embryos or counts of segments are given.

In LOCY's final contribution[1]) (Table IX, column 9) a section is given to the description of some 32 embryos ranging from a stage between BALFOUR's "B" and "C" to approximately BALFOUR's stage "K" (N.P.S. No. 4 to N.P.S. No. 25). While the central nervous system and its segmentation receives the most attention a number of the anatomical characters of the earlier stages are described. Drawings of series of transverse sections accompany the descriptions of the embryos illustrated in Figs. 8, 7, 23 and 27. The supplementary description is not continued in detail for embryos older than BALFOUR's "F", although occasional mention is made of the number of somites, and the condition of the nerves, otocyst and gill-slits. LOCY does not follow BALFOUR's classification of stages except in the case of his youngest embryo, which is listed as comparable with stage "B".

NEAL[2]), in his study of the segmentation of the nervous system (Table IX, column 9), worked upon a large series of embryos of *Squalus acanthias*. While his paper is in the main a consideration of the neuromeres, primary encephalic vesicles, and nerves, there are also many observations upon the head and trunk somites, gill slits, etc., and a large series of illustrations. The first six figures are of the external form of young embryos of from four to eleven somites. Figs. 7 to 21 inclusive are of the pharyngeal and cephalic regions of cleared specimens showing the outline of the brain, cephalic nerves, head somites, and gill slits. The nineteen stages represented by these figures together with another stage, a somewhat diagrammatic reconstruction of which is given in Fig. 40, are listed in Table IX. NEAL correlated three of his stages with those of BALFOUR as is shown in the table below.

Table V.

Tabulation of NEAL's correlation of certain of his specimens of *Squalus acanthias* with BALFOUR's stages.

NEAL's specimens		BALFOUR's stages
Fig.	Number of segments	
13	28—30	Early H
17	50	K
19	65	K

A section of JOHNSTON's paper[3]) (Table IX, column 14), upon the morphology of the fore-brain vesicle in vertebrates contains a description of this structure in *Squalus* and a series of four plastic reconstructions which illustrate, besides the fore-brain, the structure of the pharynx, nerves and head somites. These stages represented by these reconstructions are approximated with BALFOUR's stages as follows:

1) W. A. LOCY (1895), Contribution to the structure and development of the vertebrate head. Journ. Morph., Vol. 11, p. 497—586, 4 pls.

2) H. C. NEAL (1898), The segmentation of the nervous system in *Squalus acanthias*. Bull. Mus. comp. Zool. Harvard College, Vol. 31, p. 147—294, Pls. I—IX.

3) J. B. JOHNSTON (1909), The morphology of the fore-brain vesicle in vertebrates. Journ. comp. Neur. Psych., Vol. 19, p. 457—539, 45 figs.

Table VI.

Tabulation of JOHNSTON's correlation of a series of *Squalus acanthias* embryos with BALFOUR's stages.

JOHNSTON's specimens		BALFOUR's stages
Fig.	Number of segments	
5	15	G
16	24	H
15—17	42	I
18	—	late K

Two comparatively recent works have appeared dealing with the embryology of the Chimaeroid fishes: SCHAUINSLAND's on *Callorhynchus* and DEAN's on *Chimaera colliei.*

SCHAUINSLAND[1]) (Table IX, column 12) figures a series of embryos, two of which are intermediate between BALFOUR's "A" and "B". The normal plate 2 and others corresponding roughly to BALFOUR's "G", "H", "I", "K", "L" and "O". No description is given of the anatomy as a whole of this series but the gastrulation, and development of the skin, cranial nerves, teeth and extremities are considered.

DEAN's[2]) (Table IX, column 13) paper on Chimaeroid fishes is to a large extent a description of the development of *Chimaera colliei.* The egg and eggenvelopes, fertilization, segmentation, and gastrulation, are described in detail, and the general features of stages corresponding to BALFOUR's "D", "E", "F" and "G", are described and illustrated by series of sections. Of the later stages, only notes on the skull, gill slits, and extremities, are given, although mention is made of the condition of the central nervous system, pronephros, eye and digestive tract. The contribution includes an extensive series of figures, — the most complete yet published of elasmobranch embryos, — from the unsegmented blastoderm to the adult fish. A number of the embryos figured are correlated by the author with BALFOUR's stages. This correlation is given below in tabular form.

Table VII.

Tabulation of DEAN's correlation of *Chimaera colliei* embryos with stages of BALFOUR's series.

DEAN's specimens		BALFOUR's stages
Figure	Age in days	
34	—	B
35	—	"late B"
36, 40	21	D
37, 41	24	F
38, 41a, 41b	28	G
42, 42a, 42b	—	G*
43, 43a, 43b	33	"G* or I"
44	—	J
45	—	K
46	90	"Somewhat older than L"
49	130	N
50	180	P

1) 1903, H. SCHAUINSLAND, Beiträge zur Entwickelungsgeschichte und Anatomie der Wirbeltiere, I. Zoologica, Bd. 39.
2) 1906, B. DEAN, Chimaeroid fishes and their development. Carnegie Institution of Washington, Publ. No. 32, 194 pp. 11 pls., 144 figs.

In December of last year there appeared a paper by UNGARO [1]) in which is proposed a new set of subdivisions of the period of development preceding BALFOUR's "Stage L". As indicated by their nomenclature, these subdivisions are based in the main upon changes in structure and to only a slight extent upon external appearance. UNGARO's work is based upon a study of *Pristiurus melanostomus*. His correlation of the proposed subdivisions with the BALFOUR stages (as modified by HIS und the ZIEGLER's) is reproduced below.

Table VIII.

Tabulation of UNGARO's correlation of his proposed stages with those of BALFOUR (as modified by HIS and the ZIEGLERS).

UNGARO's stages		BALFOUR's stages
I Fase di segmentazione o preembrionale		
II Fase di gastrulazione	1° periodo — di gastrulazione propriamente detta	A
	2° periodo — mesodermico	B
III Fase iniziale di organogenesi (neuro-cordale)		C—D—E
IV. Fase del pronefro o branchiale	1° periodo — della formazione del canale neurenterico	
	2° periodo — di evoluzione del pronefro	F—K
	3° periodo — di involuzione del pronefro	

Description of general correlation table.
(Table IX.)

The general purpose of this table has already been described. The normal plate series and the series of the ten papers considered above have been arranged in vertical columns. A horizontal column has been assigned to each member of the normal plate series. The members of the other series have been arranged under their respective columns each in the space of the normal plate stage with which it seemed to best correspond. In some cases the symbol of stage is preceded by a bracket which includes two or more spaces of the normal plate stages. Such an arrangement indicates that the stage thus represented possesses characters common to the several inclosed normal plate members. Stages of other authors which apparently lie between two members of the normal plate series are placed in the line intervening between their spaces. A question mark follows the designation of those stages whose correlation seemed particularly doubtful.

In many cases the author has used some symbol, letters or figures, to designate his stages and these symbols have been employed in the table. When such was not the case, the number of the figure which illustrates the embryo in the original publication is used for this purpose.

Besides the number of each stage there are included in separate columms under the normal plate heading the length, number of segments, and numbers of the embryos in the Harvard embryological collection. The number of somites in the last three instances has been determined from cleared specimens of the same stage and is therefore only approximate.

1) 1910, V. UNGARO, Studi sullo sviluppo dei Selaci (*Pristiurus melanostomus* BP.). Anat. Anz., Bd. 37, p. 636—644.

Normal Plate Series No.	H.E.C. No.	Length in mm.	Number of somites	LEYDIG, 1852. *Squalus acanthias*	HIS, 1876. *Pristiurus, Scyllium*	BALFOUR, 1876. *Torpedo, Pristiurus, Scyllium canicula*	KASTSCHENKO, 1888. *Scyllium canicula, S. catulus, Torpedo ocellata, Raja* sp.	ZIEGLER, F. and ZIEGLER, H. E., 1892. *Torpedo ocellata*	HIS, 1894. A *Pristiurus.*	HIS, 1894. B *Scyllium canicula, Torpedo ocellata*	LOCY, 1893. *Squalus acanthias*	LOCY, 1895. *Squalus acanthias*	NEAL, 1898. *Squalus acanthias*	EMMERT, 1900. *Torpedo marmorata*	SCHAUINSLAND, 1903. *Callorrhynchus*	DEAN, 1906. *Chimaera colliei*	JOHNSTON, 1909. *Squalus acanthias*	UNGARO, 1910. *Pristiurus melanostomus*	Normal Plate Series No.
1	986	Blastoderm 3.0	—				IV									31		Fase I	1
2	989	Blastoderm 4.0	—			A	V									32?		1° periodo	2
					XXXIX		VI?								90, 89	33		Fase II	
3	990	Embryo 0.3	—				VII		1									2° periodo	3
					XXXVII	B			2, 3, 4							34			
4	983	1.4	—						5			1							4
							VIII	Stad. B											
5	988	1.6	—									25				35			5
					XX	C			6	11									
6	984	1.8	—								1	2, 26							6
							IX	Stad. C	7	8		3, 27							
7	1009	2.0	4—5			D			8	1, 12	2		4			36			7
					I	E						4, 5							
8	1354	2.5	9			F			9?	13		7, 30						Fase III	8
											3	8							
9	997	2.7	10—11								4	6, 9, 10							9
					XXI ?			Stad. D		II	5, 6	11, 12							
10	1011	3.1	11							14			5	I					10
11	978	3.2	11—12				X												11
										III			6						
12	994	3.2	13—14							15						37			12
13	980	3.3	15														Fig. 5		13
14	982	3.5	16—17										7					1° periodo	14
							XI	Stad. F						II					
15	1499	3.25	15		Fig. 6	G							8						15
													9	III					
16	930	4.0	19		XVI			Stad. G					10			38			16
						H							11		No. 4				
17	1498	3.8	25—26					Stad. H					12	IV		42?	Fig. 16		17
18	1398	4.8	26—27										13					Fase IV; 2° periodo	18
													14		No. 11				
19	1497	5.8	33			I													19
20	1352	5.2	35—36										15						20
													16				Figs. 15, 17		
21	1637	6.2	50—51																21
													17						
22	1503	7.5	53—54																22
								Stad. I, K					18		No. 6				
23	1495	9.0	63													45?			23
													19						
24	206 207 208	11.5	65			K												3° periodo	24
																46	Fig. 18		
25	223 224 226	13.0	70			L									No. 8				25
															No. 15				
26	227 228 229	15.0	86	"Embryo 7''' lang"											No. 16				26
						M?													
27	203 204 205	18.0	—										20					?	27
						N?									No. 14			?	
28	1494	20.6	—										21?			49?			28
29	1492	24.7	—	"Embryo 1'' lang"															29
30	1357 231 233	28.0	—																30
						O?													
31	202 362 186	34.0	—																31
32	363 176 353	37.0	—																32

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1908 Nervous System, general.
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Eismond, J. P.
1898 Gastrulation.
1903 „
Emmert, J.
1900 Embryology, general.
1900 Blood Vessels.
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Ewart, J. C.
1887 Cephalic Nerves.
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1890 Gills.
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1890 „ „
1891 Lateral Line.
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Florman, A. H. 1819 Paired Fins Skeleton.
Fohmann 1827 Thymus.
Foote, E. 1897 Skeleton.
Forssell, 1899 Lateral Line.
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Franz, V.
1905 Eye
1906 „
Fritsch, A.
1890 Fins, general.
1893 Paleontology.
Fritsch, G.
1878 Brain.
1883 Electrical Organ.
1884 „ „
1884 „ „
1884 „ „
1888 Lateral Line.
1889 Electrical Organ. Nerves, general.
1890 Electrical Organs.
1890 Nerve Cells.
1892 Nerves, general.
1894 Electrical Organ.
Fritsche, E.
1910 Thymus.
1910 „
Froriep, A.
1887 Cephalic Nerves.
1891 „ „
1891 „ „
1892 Head — Cephalic Nerves.
1901 Nerves, general.
1902 Head
1902 „
Fuchs, S. 1895 Lateral Line.
Fuchs, F. 1908 Brain.
Fürbringer, K.
1903 Skeleton
1903 „
1904 „
Fürbringer, M.
1878 Urogenital System, general.
1895 Skeleton — Skeletal Muscle.
1897 Spinal Nerves.
1902 Fins, general — Cephalic Nerves.
1903 Skeleton.

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Gadow, H.
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Gadow, H., and Abbott, E. C. 1895 Skeleton.
Galeotti, G. 1897 Brain.
Garman, H. 1892 Lateral Line.
Garman, S.
General.
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1888 Lateral Line.
1904 General.
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Gaskell, W. H. 1908 General.
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Gaupp, E.
1898 Axial Skeleton.
1898 Epiphysis.
1901 Axial Skeleton.
1904 Skeleton.
Gawrilenko, A. 1910 Nose.
Gegenbaur, C.
1865 Fins, Paired.
1865 „ „
1865 Skeleton — Fins, Paired.
1865 Heart.
1870 Fins, general.
1870 „ „
1871 Cephalic Nerves — Segmentation, Head.
1872 Axial Skeleton — Head.
1873 Fins, general.
1876 „ „
1878 Digestive Tract, general.
1879 Fins, general.
1884 Abdominal Pores.
1886 Heart.
1887 Head.
1887 Axial Skeleton.
1892 Intestine.
1894 Fins, Paired.
Gentes, L.
1906 Hypophysis.
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Gerbe, Z.
1872 Egg.
1872 Segmentation.
Gerhardt, U. 1908 Male Urogenital System.
Gervais, P.
1876 General.
1876 „
Giacomini, E.
1893 Embryonic Appendages.
1894 Female Urogenit. System.
1894 Embryonic Appendages.
1895 „ „
1898 Interrenals.
1903 Embryonic Appendages.
1904 Interrenals.
Giannelli, L. 1900 Pancreas.
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Giglio, J. E. 1902 Cephalic Nerves.
Gill, T.
1864 Systematic.
1905 Egg Envelopes.
Giltay, C. M. 1834 Interrenal — Sympathetic.
Girard, C. 1854 General.
Girardi and Pratalongo 1786 Electrical Organs.
Gley, E. 1904 Blood.
Goette, A.
1878 Axial Skeleton.
1879 „ „
1901 Gills.
Goodey, T.
1910 Thyreoid.
1910 Skeleton.
Goodrich, E. S.
1902 Fins, Paired.
1904 Fins, general.
1906 „ „
1909 General.
Goodsir, J. 1856 Electric Organs.
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Gouan. 1770 General.
Goyeau. 1760 Teeth.
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1897 „ „ „
Gregory, W. K. 1904 Skeleton.
Greil. 1908 Blood.
Grew, N. 1676 Digestive Tract, general.
Grieg, J. A. 1899 Egg Envelopes.
Grosglik, S. 1885 Urogenital System, general.
Grosser, O.
1906 Teratology.
1907 Blood Vessels.
1908 Foetal Appendages.
Grynfeltt, E.
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1903 „
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Gudger, E. W. 1907 Habits.
Guiart, J. 1896 Thyreoid.
Guillot, M. 1845 Blood Vessels.
Gulliver, G. 1872 Blood.
Gunnerus, J. E. 1770 Embryology, general.
Günther, A. C. L. G.
1859—61 General.
1870 General.
1880 „
Guthke, E. 1906 Cephalic Nerves — Segmentation, Head — Lateral Line.

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Haller, B.
1896 Hypophysis.
1898 Brain.
1901 Urogenital System, general.
Hallman, E. 1840 Spermatozoa.
Hammar, J. A.
1893 Liver.
1910 Thymus.
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Hannover, A. 1868 Scales.
Harless, E.

1846 Brain.
1850 Teeth.
Harman, N. 1899 Eye.
Harmer, T. 1767 Breeding Habits.
Hartmann, R. 1876 General.
Hasse, C.
1873 Inner Ear.
1877 Paleontology.
1877 Embryology, general.
1879—82 General — Axial Skeleton.
1879 Connective and Supporting Tissue.
1883 General.
1892 Axial Skeleton.
1878 Embryology, general.
Haswell, W. A.
1894 Skeleton.
1897 Embryology, general.
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Hawkes, O. A. M.
1905 Pharynx — Nerves, Spinal.
1906 Nerves, Cephalic.
1906 Gill Slits.
1907 General Anatomy — Gill Slits.
Hay, O. P. 1901 Paleontology.
Heincke, F. 1873 Teeth.
Helbing, H.
1902 General.
1903 Intestine.
1904 General.
Held, H. 1909 Nervous System, general.
Hellman, 1898 Ear.
Helly, K. 1905 Cytology.
Hendricks, K. 1908 Gills.
Henle, J. 1878 Eye.
Hérissant, 1749 Teeth.
Hermann, F.
1889 Spermatozoa.
1897 „
1897 „
1898 „
Herrick, C. J.
1903 Sense Organs, general.
1903 Lateral Line.
Herrmann, G.
1881 Spermatozoa.
1882 „
Hertwig, O.
1874 Scales and Teeth.
1876 Scales.
Hilgendorf, F.
1888 Teeth.
1891 „
Hill, R. 1851 Urogenital System, general.
His, W.
1877 Embryology, general.
1877 „ „
1879 Nerves, general.
1887 Central Nervous System, general—Cephalic Nerves.
1889 Nervous System, general.
1892 Brain.
1892 Embryology, general.
1893 Brain.
1894 Embryology, general.
1894 Germ Layers.
1894 „ „
1897 „ „
Hoek, P. P. C. 1891 Urogenital System.
Hochstetter, F.
1887 Blood Vessels.
1893 „ „
1900 Coelum — Blood Vessels.
1905 Blood Vessels — Embryonic Appendages.
Hoffmann, C. K.
1881 Embryology, general.
1883 Segmentation.
1886 Urogenital System, general.
1892 Blood Vessels.
1893 Blood.
1893 Blood Vessels.
1894 Cephalic Nerves.
1896 „ „
1897 „ „
1899 „ „
1900 Urogenital System, general — Sympathetic — Spinal nerves.
1901 Blood Vessels.
Hofmann, M. 1901 Blood Vessels.
Holm, J. F.
1894 Nose.
1897 Liver.
Holmgren, E.
1898 Spinal Nerves.
1900 Nerve Cells.
Homburger, R. 1904 Paired Fins.
Home, E.
1807 Stomach.
1809 General Anatomy.
1810 „ Embryology.
1814 „ Anatomy.
Houser, G. L. 1901 Nerve Cells.
Houssay, F. 1908 General.
Howes, G. B.
1883 Ear.
1887 Paired Fins.
1890 Urogenital System.
1890 Paired Fins.
1890 Blood Vessels.
1890 Digestive Tract.
1890 Paired Fins.
1890 Digitiform Gland.
1890 General Anatomy — Coelom.
1891 Systematic.
1891 Ear.
1891 Paired Fins.
1892 Urogenital System, general.
1897 Egg.
Hoyer, H. 1892 Spleen.
Huber, O.
1901 Urogenital System, Male.
1901 „ „ „
1908 „ „ „
Hubrecht, A. A. W.
1876 Axial Skeleton.
1876 Systematic.
1877 Axial Skeleton.
Humboldt, A. v.
1809 General.
1836 Electrical Organs.
Humphrey, F. M. 1872 Skeletal Muscles.
Hunter, J.
1773 Electrical Organs.
1782 Ear.
1792 Ear.
Huxley, J. H. 1876 General.
Hyde, I. H. 1904 Brain.
Hyrtl.
1843 Blood Vessels.
1854 Female Urogenital System — Blood Vessels.
1858 Blood Vessels.
1861 Urogenital System, general.
1872 Blood Vessels.

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Imms, A. D. 1905 Teeth.
Iwanzoff, N.
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1895 „ „

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Jacobaeus, O. 1680 General Anatomy.
Jacobson, L. L.
1813 Sense Organs.
1821 Blood Vessels.
1834 Gills.
Jaekel, O.
1889 Paleontology.
1891 Systematic.
1891 Paired Fins.
1892 Fins — Paleontology.
1892 Paleontology.
1893 „
1894 „
1897 General.
1899 Skeleton — Paleontology.
1899 General.
1899 „
1899 Paleontology.
1901 Egg and Egg Envelopes — Paleontology — Teeth.
1906 Paleontology.
Jaquet, M.
1897—99 Skeletal Muscle — Axial Skeleton.
1905 Skeleton.
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Jentsch, B. 1897 Teeth.
Jobert. 1844 Electrical Organs.
Johann, L. 1899 Luminous Organs.
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Johnston, J. B.
1902 Lateral Line.
1902 General Nervous System.
1904 Cephalic Nerves.
1905 Head — Brain.
1906 Central Nervous System.
1910 Brain.
1910 Segmentation Head — Brain — Cephalic Nerves — Epiphysis.
Jones, T. R. 1847 General.
Jordan, D. S. 1891 Axial Skeleton.
Joseph, H. 1906 Egg.
Jourdain, S.
1859 Blood Vessels.
1868 Lymphatics — Veins.
Jungersen, H.
1898 Paired Fins.
1899 Male Urogenital System.

K.

Kalberlah, F. 1900 Spinal Cord.
Kallius, E.
1898 Eye.
1901 „
Kantorowicz, R. 1898 Intestine.
Kappers, C. U. A.
1904 Brain.
1906 „
Kastanajan, E. M. 1902 Brain.
Kästner, S.
1892 Skeletal Muscle.
1892 „ „
Kastschenko, N. T.
1888 Embryology, general — Germ Layers — Segmentation.
1890 Ovum.
1894 Segmentation.
1894 „
1895 Germ Layers.
Kerr, J. G. 1907 Skull.
Killian, G. 1891 Segmentation.
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Klaatsch, H.
1890 Scales.
1893 Axial Skeleton.
1896 Paired Fins.
1897 Subnotal Rod.
Klinkhardt. 1905 Cephalic Nerves — Lateral Line.
Kneeland, S. 1847 General Anatomy.
Kohn, A.
1899 Suprarenal.
1903 „
Kölliker, A. v.
1856 Electrical Organs.
1856 Electrical Organs — Nerve Endings — Nose.
1857 Electrical Organs.
1859 Notochord.
1859 Notochord — Axial Skeleton.
1860 Notochord — Axial Skeleton.
1860 General Anatomy.
1863 Axial Skeleton.
1865 „ „
1885 Germ Layers.
Kollmann, J.
1884 Germ Layers.

1885 Embryology, general.
1885 „ „
1886 Segmentation.
Kopsch, F.
1897 Breeding Habits.
1898 Gastrulation.
1898 Embryology, general.
Kowalevsky, A. 1870 Embryology general.
Krall, A. 1908 Paired Fins.
Krause, R.
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Krause, W.
1886 Nerves, general.
1886 Electrical Organs — Nerve Endings.
1886 Eye.
1887 Electrical Organs — Nerve Endings.
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Krukenberg, C. F. W.
1877—78 Digestive Tract, general.
1882 Digestive Tract, general.
1885 Egg Envelopes.
Kuhl, H. 1820 Skeleton — Head — Paired Fins.
Kupffer, C. 1891 Cephalic Nerves.
Kwietniewski, C. 1905 Skin.

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Laaser, P.
1900 Teeth.
1903 „
Lacépède. 1798—1803 General.
Lafite-Dupont. 1910 Blood Vessels.
Laguesse, E. G.
1888 Spleen.
1891 Urogenital System, general — Supporting Tissues.
1894 Spleen.
1894 Pancreas.
1902 „
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1903 Spleen.
1906 Pancreas.
Lallemand. 1841 Spermatozoa.
Lamb, A. B. 1902 Skeletal Muscle — Cephalic Nerves — Head Somites.
Lankester, E. R. 1879 Heart.
Latham, J. 1794 General.
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Lea, F. S. 1898 Ear — Lateral Line.
Lebeninsky, J. 1894 Urogenital System, general.
Legroff, A. 1875 Median Fins.
Lenhossék, M. V. 1892 Spinal Cord — Spinal Nerves.
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1836 Gills.
Leuckart, R.
1847 Urogenital System, general.
1850 Embryology general.
1875 Eye.
1895 Embryology, general.
Leuret, F., and Gratiolet, P. 1839 Nervous System, general.
Levi, G. 1906 Nerves, general.
Lewis, F. T. 1904 Blood Vessels.
Leydig, F.
1851 General Anatomy.
1852 General Anatomy — Embryology, general.
1853 General Anatomy.
1857 „ „
1876 Lateral Line — Skin.
1903 Luminous Organs.
Locy, W. A.
1893 Nervous System, general.
1894 Embryology, general.
1894 Eye.
1894 Eye.
1895 Cephalic Nerves.
1896 Eye — Cephalic Nerves — Segmentation Head.
1897 Segmentation Head.
1899 Cephalic Nerves.
1899 „ „
1905 Brain.
Lombard, G. D. 1909 Thyreoid.
Lorenzini, Stefano 1678 Lateral Line.
Lubosch, W. 1909 Supporting Tissues.
Lilljeborg, W.
1866 Electrical Organs.
1880 Embryology, general.
List, H.
1884 Cytology.
1884 Cytology — Urogenital System, general.
1885 Cytology — Urogenital System, general.
1885 Cytology — Urogenital System, general.
1885 Cytology — Skin.
1885 Cytology.
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Lwoff, B. 1887 Notochord.

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Malm, A. W. 1876 General.
Marcy. 1893 General.
Maréchal, J.
1904 Ovum.
1907 Ovum.
1910 „
Marion, G. E.
1905 Skeletal Muscle.
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Markert, F. 1896 Supporting Tissues — Fins, general.
Marqua, F. 1880 Embryology, general.
Marshall, A. M.
1881 Cephalic Nerves.
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1890 Segmentation Head — Cephalic Nerves.
Martino, A.
1846 Spermatogenesis.
1848 „
Matteucci and Savi.
1844 Electrical Organs.
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Matthews, J. D. 1885 Urogenital System, general — Teratology.
Maurer, F.
1891 Skeletal Muscle.
1894 „ „
1895 Skin.
Mayer, F. J. C.
1834 Electric Organs.
1834 Fins, general.
Mayer, P.
1886 Unpaired Fins.
1888 Gills.
1889 Blood Vessels.
1893 „ „
1894 Swimm Bladder.
1897 Spinal Valve.
Mayr, J. 1898 Pancreas.
Mazza, F.
1895 Spermatogenesis.
1896 General Anatomy.
Mazza and Peruggia. 1894 Digitiform Gland.
Meckel, J. F. 1824 General.
Meek, A.
1909 Cephalic Nerves — Segmentation Head.
1910 Segmentation Head.
Mehrdorf, C. 1890 Gestation.
Meier, F. 1875 Urogenital System, general.
Menci, E. 1902 Brain.
Mencl, E. 1902 Nerve Cells.
Merkel, F. 1880 Nerve Endings.
Merritt, O. A. 1902 Cephalic Nerves.
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1879 General.
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Mingazzini, P. 1889 Skeletal Muscle.
Minot, C. S.
1892 General Works.
1901 Epiphysis.
Mitchill. 1803 General Anatomy.
Mitrophanow, P. J.
1889 Lateral Line.
1890 Ear.
1893 Nerve Cells.
1893 Embryology, general.
1894 Cytology.
Mivart, Sv. G. 1879 Fins, general.
Molin, R. 1859 Skeleton.
Mollier, S.
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1893 Unpaired Fins.
1894 Paired Fins.
Monro, A.
1757 Lymphatics.
1785 General.
Monti, R.
1898 Stomach.
1898 Digestive Tract — Nervous System, general.
Moore, J. E. S.
1894 Spermatogenesis.
1894 Embryology, general.
1895 „ „
1896 „ „
1897 „ „
Moroff, T. 1904 Gills.
Morrill, A. D. 1897 Ear.
Mosso, A. 1888 Blood.
Mudge, G. P.
1905 Teratology.
1906 „
Müller, E. 1909 Paired Fins.
Müller, H.
1851 Lateral Line.
1851 „ „
1852 „ „
1852 Electrical Organs.
1852 Systematic.
Müller, J.
1831 Male Urogenital System.
1842 Urogenital System, general.
1840 Gestation.
1843 Heart — Nerves.
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Müller, J., and Henle, J. 1841 Systematic.
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Neal, H. V.
1896 Segmentation Head.
1897 Skeletal Muscle.
1898 Segmentation Head.
1898 Brain — Cephalic Nerves — Head Somites.
1900 Cephalic Nerves.
1903 „ „
1909 Segmentation Head.
1909 Cephalic Nerves.

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Neuville, H.
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1897 „ „
1898 Spleen.
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Onodi, A. D.
1884 Nerves, Spinal.
1885 Sympathetic.
1886 Nervous System, general.
1887 „ „ „
1887 Cephalic Nerves.
1901 „ „
Oppel, A.
1896 General Anatomy.
1900 Digestive Tract.
1900 General Anatomy.
1901 Digestive Tract.
1904 „ „
Ostroumoff, A.
1889 Cephalic Nerves
1889 Gastrulation.
1889 Segmentation Head.
Owen, R.
1839 Teeth.
1832—40 General.
1840—45 Teeth.
1846 General Anatomy.
1866 „ „
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1867 Gills.
1869 „
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Parchappe, M.
1848 Heart.
1848 „
Parker, G. H., and Davis, F. K.
1899 Heart.
1899 „
Parker, N. W., and Burland, F. H.
1909 Male Urogenital.
Parker, T. J.
1879 Spiral Valve.
1881 Blood Vessels.
1882 Embryology, general.
1882 Gestation.
1886 Male Urogenital.
1887 Blood Vessels.
1887 „ „
1887 General Anatomy.
1889 Embryonic Appendages.
1890 Axial Skeleton.
1890 „ „
1895 Text Books.
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Pavesi, P.
1874 General.
1878 „
Peabody, J. E.
1896 Embryology, general.
1897 Lateral Line.
Pearson, J. T. 1835 Embryology, general.
Perényi, J.
1886 Notochord.
1887 „
Perravex, E. Egg and Egg Envelopes.
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Petelenz, J. 1886 Nerves.
1886 Electrical Organs.
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Pettit, A.
1896 Suprarenal.
1905 Blood.
Philipeaux and Vulpian.
1853 Cranial Nerves — Brain.
Phisalix. 1885 Spleen.
Phipson, F. L.
1860 Luminous Organs.
1874 General — Egg.
Pighini, G.
1904 Nervous System, general.
1905 Nerve Cells.
1908 Nerve Cells — Nerve Endings.
1908 Electrical Organs.
Pilliet, A.
1885 Digestive Tract, general.
1890 Liver.
1890 Lymphatics.
1893 Skin.
Pinkus, F. 1905 Cephalic Nerves.
Pinto, C.
1903 Spleen.
1904 „
Pitzorno, M.
1905 Blood Vessels.
1910 Sympathetic.
Pixell, H. T. M. 1908 Digitiform Gland.
Platt, J. B.
1890 Head Cavity.
1891 Segmentation — Head.
1891 Cephalic Nerves — Head Cavities — Blood Vessels — Head.
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1897 Ear.
1897 „
Policard, A. 1902 Lymphatics — Genital Gland.
Poll, H. 1903 Suprarenal.
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Portlock. 1845 Egg.
Pouchet, G.
1882 Spleen.
1882 Blood.
Priem, E. or F.
1897 Teeth.
1898 Paleontology.
Punnett, R. C.
1901 Variation — Nerves, Spinal.
1904 General.
Purvis, G. C. 1890 Nerve Endings.
Putnam, F. W.
1870 Embryology, general.
1875 Urogenital System, general.

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Quinton, R. 1906 General.
Quix. 1903 Ear.

R.

Rabl, C.
1892 Blood Vessels.
1896 Urogenital System, general.
1897 Urogenital System, general — Mesoderm — Fins, general.
1898 Eye.
1901 Fins, general.
Rabl-Rückhard, H.
1880 Notochord — Hypophysis — Skull.
1893 Brain.
1894 „
Raffaele, F.
1891 Blood Vessels.
1901 Germ Layers.
Rand, H. W.
1905 General Anatomy.
1905 Blood Vessels.
1907 Gills.
Ranvier, L. A.
1872 Nervous System, general.
1875 Nerve Endings — Electrical Organs.
1875—78 Electric Organs.
1878 Nervous System, general. Electrical Organs.
Rathke, H.
1825 Urogenital System, general.
1827 Gills.
Rauber, A. 1883 Germ Layers.
Rawitz, B.
1899 Blood.
1899 Spermatogenesis.
1899 Blood.
Redeke, H. C.
1898 Urogenital System, general.
1899 Urogenital System, general — Egg Envelopes.
1910 Digestive Tract.
Reese, A. M. 1910 Lateral Line.
Regan, C. T.
1906 Systematic.
1907 Integument.
Reichenheim, M.
1873 Brain.
1876—77 Chord.
Reichert, C. B.
1856 Urogenit. System, general.
1877 Notochord.
Reighard, J. 1902 Head Cavities.
Reis, O.
1890 Paleontology.
1891 General Anatomy.
1895 Teeth — Integument.
1895 Skeleton.
1896 Skin.
Remak, R.
1837 Sympathetic.
1856 Nerve Endings.
Rennie, J. 1906 Teratology — Fins.
Retzius, A. A.
1819 Stomach.
1845 Electric Organs.
1848 „ „
Retzius, G.
1877 Spinal Nerves.
1878 Paired Fins.
1881 Ear.
1895 Spinal Chord.
1896 Eye.
1898 Nerve Endings — Electrical Organs.
1898 Lateral Line.
1902 Spermatozoa.
1904 Central Nervous System.
1905 Eye.
1909 Spermatozoa.
Rex, H. 1891 Blood Vessels.
Reynolds, S. H. 1897 Skeleton.
Ricci, N. 1875 Stomach.
Ridewood, W. G.
1895 Gill Slits.
1896 Teeth.
1897 Skeleton.
1898 „
1899 Unpaired Fins.
1899 Eye.
Risso. Systematic.
Robin, C.
1845 Blood Vessels.
1845 „ „
1845 „ „
1845 Lymphatics.
1845 Blood Vessels — Lymphatics.
1846 Blood Vessels.
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1847 „ „
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1847 Gills.
1847 Thyreoid.
1848 Blood Vessels.
1849 Male Urogenital System.

Robin, H. A. 1867 Lymphatics.
Robson. 1886 Breeding Habits.
Rohon, J. V.
1877 Brain.
1878 Brain — Cephalic Nerves.
Romano, A.
1897 Brain.
1902 Nerve Cells.
1902 „ „
1899 Brain.
Röse, C.
1890 Heart.
1894 Teeth.
1894 „
1894 „
1895 „
1897 Supporting Tissue.
Rosenberg, E.
1884 Skeleton.
1886 Skull.
Rossi, U. 1902 Hypophysis.
Rosted, E. 1788 Teeth.
Rouget, C.
1876 Electric Organs.
1876 Nerve Endings.
1877 „ „
Rouvière, H. 1906 Skeletal Muscles.
Rouvière and Ladreyt. 1906 Blood.
Rückert, J.
1885 Germ Layers.
1887 Germ Layers — Blood.
1888 Heart.
1888 Urogenital System, general.
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1889 Urogenital System, general.
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1899 Segmentation.
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Ruffini, A. 1904 Spleen.
Ruge, E. 1902 Paired Fins.
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1886 Segmentation.
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Rynberk, G. van
1904 Integument — Spinal Nerves.
1906 Eye.
1906 General.
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1908 Integument.

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Sabatier, A.
1874 Blood Vessels.
1882 Spermatogenesis.
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1896 „
1898 Fins.
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Salvi, G. 1907 Blood Vessels.
Salvianus, H. 1554 Lateral Line.
Samassa, P. 1895 Germ Layers.
Sanctis, X. 1873 Electrical Organs.
Sander, J. 1867 Brain.
Sanders, A.
1882 Brain.
1887 „
Sanfelice, F.
1888 Spermatogenesis.
1889 Blood.
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1890 Blood.
Sappey, P. C.
1874—85 Lymphatics.
1880 Lymphatics.
Sargent, P. E.
1900 Brain.
1901 „
1903 „
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Sasse, H. F. A. 1886 Hypophysis.
Sauerbeck, E. 1896 Brain.
Sauvage, H. E. 1889 Embryology, general.
Savi, P. 1844 Electrical Organs.
Scarpa, A.
1789 Ear.
1789 Nose.
Schacherl, M. 1902 Spinal Chord.
Schaffer, J. 1901 Supporting Tissue.
Schaper, A.
1898 Brain.
1899 Eye.
Schauinsland, H.
1901 Embryology, general.
1903 General Embryology — Teeth — Skull — Brain — Cranial Nerves — Paired Fins.
Schenk, S. L.
1874 Egg.
1874 Embryonic Appendages.
1875 Gills, Filaments.
1876 Brain.
1879 Embryology, general.
Schiefferdecker, P. 1886 Eye.
Schmidt, A. H. 1898 Ovum.
Schnaudigel, O. A. F. 1906 Nerve Cells — Eye.
Schneider, A.
1887 Skeletal Muscle.
1890 „ „
Schneider, G. 1897 Abdominal Pores — Urogenital System, general.
Schneider, J. G. 1788 General.
Schoenichen, W. 1900 Teeth.

Schoenlein, C., and Willem, V. 1895 Blood.
Schreiner, A. and K. E. 1906 Spermatogenesis.
Schultz, A.
1874 General.
1875 Embryology, general.
1876 Germ Layers.
1877 „ „
Schultze, M. S.
1858 Electrical Organs.
1859 „ „
1859 „ „
1862 Nose.
Schultze. 1817 Axial Skeleton.
Schwalbe, G. 1879 Cephalic Nerves.
Schwarz, D. 1889 Germ Layers.
Sedgwick, A.
1892 Mouth — Nose — Sympathetic.
1894 Nerves, Cephalic.
Semon, R. 1891 Urogenital System, general.
Semper, C.
1874 Urogenit. System, general.
1875 „ „ „
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Sewertzoff, A.
1895 Segmentation, Head.
1897 Skull.
1898 Segmentation, Head.
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1899 Skull — Segmentation, Head.
Shearer, C. 1898 Eye.
Sheldon, R. E. 1911 Sense Organs, general — Nose.
Shore, T. W. 1889 Cephalic Nerves.
Sidoriak, S. 1898 Ear.
Siebold and Stannius. 1854 General.
Sihleanu, St. S. 1876 Electrical Organs.
Smallwood, W. M. 1908 Eye.
Smith, A. 1837 Systematic.
Sobotta, J. 1897 Segmentation.
Solger, B.
1876 Skeleton.
1880 Lateral Line.
1880 „ „
1889 Brain.
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1902 Nerve Cells.
Spengel, J. W.
1904 Gill Slits.
1905 Teeth.
Stannius, H.
1839 General Anatomy — Thymus.
1840 Male Urogenital.
1846 Pancreas.
1849 Nerves, general.
Stark, J.
1844 Axial Skeleton.
1845 Electrical Organs.
Starks, E. C. 1901 Skeleton.
Straub, W. 1901 Heart.
Stead, D. G. 1906 Embryology, general.

Steenstra-Toussaint, A. J. D.
1839 Urogenital System, general.
1839 Urogenital System, general.
1839 General.
1843 Digestive Tract.
Steenstrup, J.
1861 General.
1874 Gills.
Steiner, J.
1886 Brain — Ear.
1900 „
Steinhart, O. 1903 Scales.
Stenosis, N.
1664 Lateral Line.
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Stephan, P.
1902 Male Urogenital.
1902 Spermatogenesis.
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1903 „
Sterzi, G. 1909 Brain — Spinal Cord.
Stewart, C.
1906 Ear.
1906 „
Stieda, L.
1872 Brain.
1873 Chord.
1873 Brain.
Stirling, W.
1885 Digestive Tract.
1891 Skeletal Muscle.
Stöhr, P.
1876 Heart.
1876 „
Straub, W. 1901 Heart.
Stricht, O. Van der. 1896 Blood — Blood Vessels.
Stromer, R. E.
1903 Paleontology.
1904 „
1904 „
Strong, O. S.
1894 Cephalic Nerves.
1903 „ „
Studnička, F. K.
1893 Epiphysis.
1894 Brain.
1895 Epiphysis.
1895—96 Brain.
1897 Notochord.
1898 Eye — Optic Nerves.
1899 Brain.
1899 Nervous System, general.
1900 „ „ „
1900 Epiphysis.
1901 Nerve Cells and Notocord.
1902 Cytology.
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1902 Mouth.
1902 Cytology (No. 2).
1902 Nerve Cells.
1903 Notocord.
1904 Supporting Tissue.
1906 Teeth.

1907 Teeth.
1909 Integument.
1909 Teeth.
Sullivan, M. X. 1907 Digestive Tract.
Sund, O.
1904 Nose.
1905 Sense Organs.
Suzuki, B. 1898 Spermatogenesis.
Swaen, A.
1883 Spermatogenesis.
1885 Blood.
1887 Embryology, general.
Swan, J. 1835 Nervous System.
Swenander, G. 1907 Embryology, general.
Szczawinska, W. 1898 Nervous System, general.

T.

Tagliani, G. 1905 Chord.
Tatham, W. 1803 General.
Thacher, J. 1576 Fins, general.
Thompson, A.
1830—31 Blood Vessels.
1833 Blood Vessels.
1846 Ovum.
Thompson, W. 1844 Egg.
Tiesing, B. 1895 Skeletal Muscle.
Tilesius, T. v. 1802 Egg.
Todaro, F.
1871 Lateral Line.
1872 Sense Organs.
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Todd, J. T. 1816 Electric Organs.
Tomes, C. S.
1876 Teeth.
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Traquave, R. H.
1888 Paleontology.
1892 Teratology.
1894 Paleontology.
Treviranus, G. R.
1805 Skeleton.
1820 Sense Organs — Nerves — Brain.
Tricht, B. van. 1907 Fins, general.
Trinchese, S. 1885 Nerve Endings.
Trois, E. F.
1866—67 Female Urogenital.
1875—76 „ „
1878—79 Blood Vessels.
1883 Spermatogenesis.
Tullberg, T. 1903 Ear.
Tur, J. 1906 Embryology, general.
Turner, W.
1873 General Anatomy.
1874 „ „
1875 „ „
1875 Gills.
1878 Female Urogenital.
1879 Abdominal Pores.
1880 Gills.

U.

Ungaro, V. 1910 General Embryology.
Ussoff, S. A. 1906 Axial Skeleton.

V.

Vaillant, L.
1877 Egg.
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1884 „
1888 Embryology, general.
1904 Skeleton — Systematic.
1908 Teratology.
Valenti, G.
1891 Nerve Cells.
1893 „ „
1894 „ „
Valentin, G. 1842 Brain.
v. la Valette-St. George. 1878 Spermatogenesis.
Vaussière, A. Ovum.
Vauquelin, L. N. 1795 Liver.
Verdun, P. 1898 Thymus — Thyreoid.
Vetter, B.
1874 Skeletal Muscle.
1878 „ „
Vialleton, L.
1902 Nervous System, general — Lymphatics.
1902 Lymphatics.
1903 „
1906 Gill Slits.
1907 Blood Vessels — Thymus.
1908 General Embryology — Thymus.
Viault, F. 1876 Brain.
Vicq d'Azyr.
1776 Brain.
1805 Eye.
Vignal, W.
1880 Ganglia.
1881 Heart.
1883 Heart — Nervous System, general.
Vincent, S.
1896 Suprarenal.
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1897 Suprarenal — Urogenital, general.
1898 Suprarenal.
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Vincenzo, C. G. 1884 Nerves.
Virchow, H.
1881 Eye.
1885 General Embryology.
1889 Gill Slits.
1889 Blood Vessels.
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1889 „ „
1890 „ „
1890 „ „
1893 Gills — Blood Vessels.
1895 Blood Vessels.
1897 Blood Vessels — Embryonic Appendages.
1897 Cytology.
1897 Yolk Sack.
1898 Blood Vessels.
1898 Germ Layers.
Vogt, C., and Pappenheim.
1859 Urogenital, general.
Vrolik, G. 1828 General Anatomy.

W.

Waalewijn, H. W. 1872 Intestine.
Wagner, R. 1847 Electric Organs.
Wahlgren, F. 1852 Nervous System.
Waite, E. R.
1896 Egg and Egg Envelopes.
1902 Embryology, general.
1902 General.
1906 „
1906 Breeding Habits.
Wallace, W. 1903 Ova.
Wallenberg, A. 1907 Brain.
Walsh, J.
1773 Electrical Organs.
1774 General.
Watney, H. 1882 Thymus.
Watson, W. 1778 General.
Weber, A. 1908 Heart.
Weber, E. H.
1817 Lymphatics.
1820 Ear.
Weber, M. 1887 Abdominal Pores.
Weinland, E. 1901 Stomach.
Weldon, W. F. R.
1885 Suprarenals.
1885 „
Werner, F. 1892 Integument.
Weyl, T. 1882 Electric Organ.
White, P. J.
1890 Skeleton.
1893 „
1895 „
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1896 „
Widakowich, V.
1905 Gestation.
1907 „
1907 Female, Urogenital.
1908 Ovum — Blood Vessels.
1908 Female, Urogenital.
Wiedersheim, R.
1883 General Anatomy.
1893 „ „
1898 „ „
1902 „ „
Wijhe, J. W. van.
1882 Cephalic Nerves — Head Cavities — Segmentation, Head.
1886 Segmentation, Head.
1886 Urogenit. System, general.
1888 „ „ „
1888 „ „ „
1889 Segmentation, Head.
1898 Urogenital, general.
1904 Skeleton.
1899 Urogenit. System, general — General — Mesoderm.
Wikström, D. A. 1897 Skeletal Muscle — Spinal Nerves.
Wilder, B. C.
1876 Brain.
1876 „
1877 „
1898 „
1905 „
1907 General.
1908 Brain.
Wils, H. B. 1844 Anatomy, general.
Woit, O. 1898 Spleen.
Wolff, W. 1884 Electrical Organs.
Wood-Mason, J. 1892 Gestation.
Wood-Mason, J., and Alcock, A. 1891 Gestation.
Woods, F. A.
1902 Germ Cells.
1902 „ „
Woodward, A. S.
1884 Paleontology.
1886 Skeleton.
1887 Paleontology.
1888 „
1892 Skeleton.
1892 Teeth.
1892 Fins.
1893 Teeth.
1895 Paleontology.
1898 „
1899 General.
Wortman, J. S. 1886 Teeth.
Wunderer, H. 1908 Nerve Endings.
Wyman, J.
1854 Electrical Organs.
1855 Embryology, general.
1859 Electrical Organs.
1864 Embryology, general.

Y.

Yung, E.
1895 Digestive Tract.
1898 „ „
1898 Digestive Tract — Pancreas.
1899 Digestive Tract.
1899 „ „

Z.

Zdarek, E. 1904 Egg.
Ziegler, H. E.
1888 Germ Layers.
1892 Blood.
1894 Embryology, general.
1902 „ „
1907 Skeleton.
1908 Cephalic Nerves — Hypophysis.
1908 Fins.
1908 Segmentation of Head.
Ziegler, H. E. and F. 1892 Gastrulation — Embryology, general — Mesoderm.
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Zouiew, B. 1789 Embryology, general.
Zuckerkandl, E. 1906 Suprarenal.

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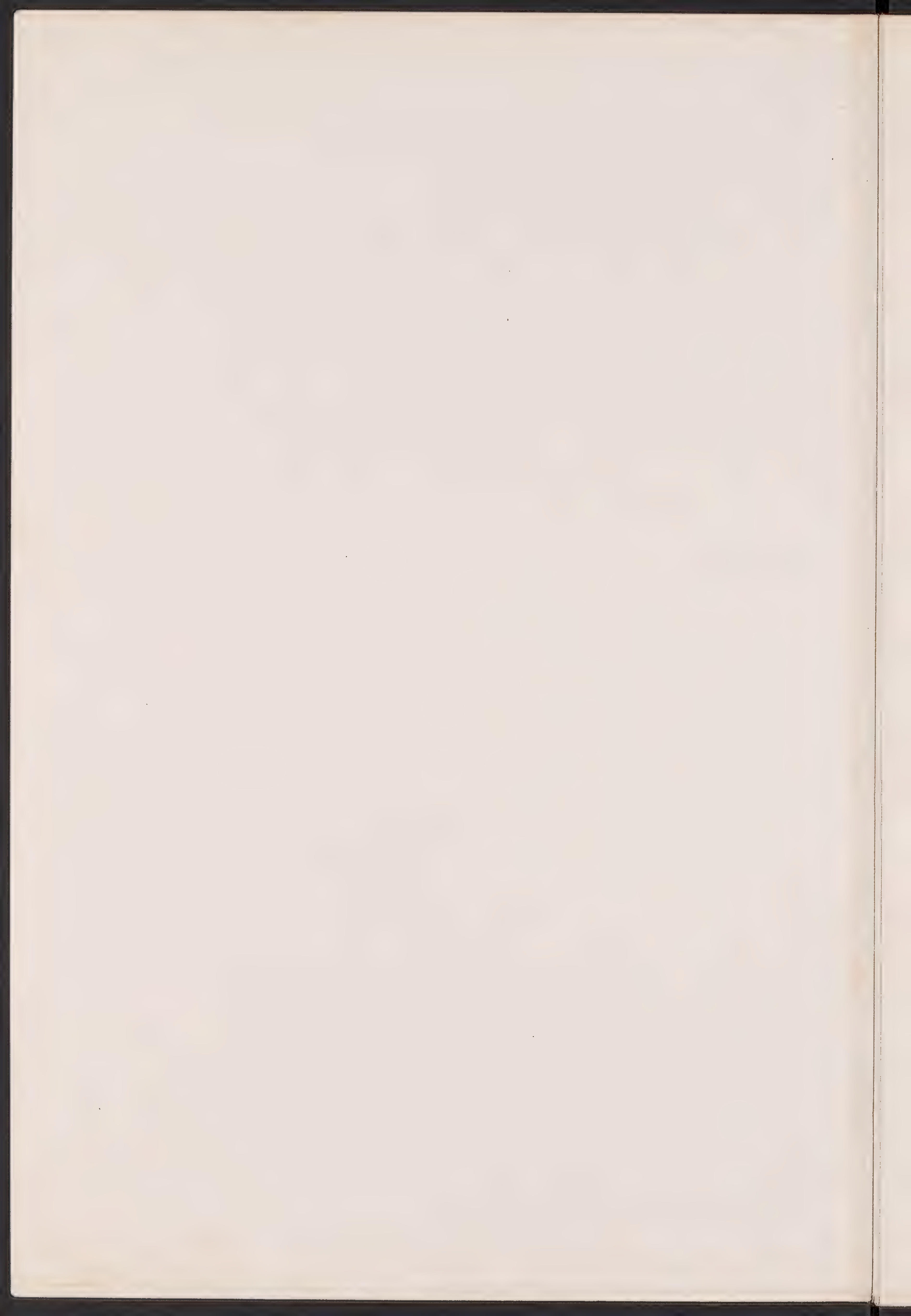


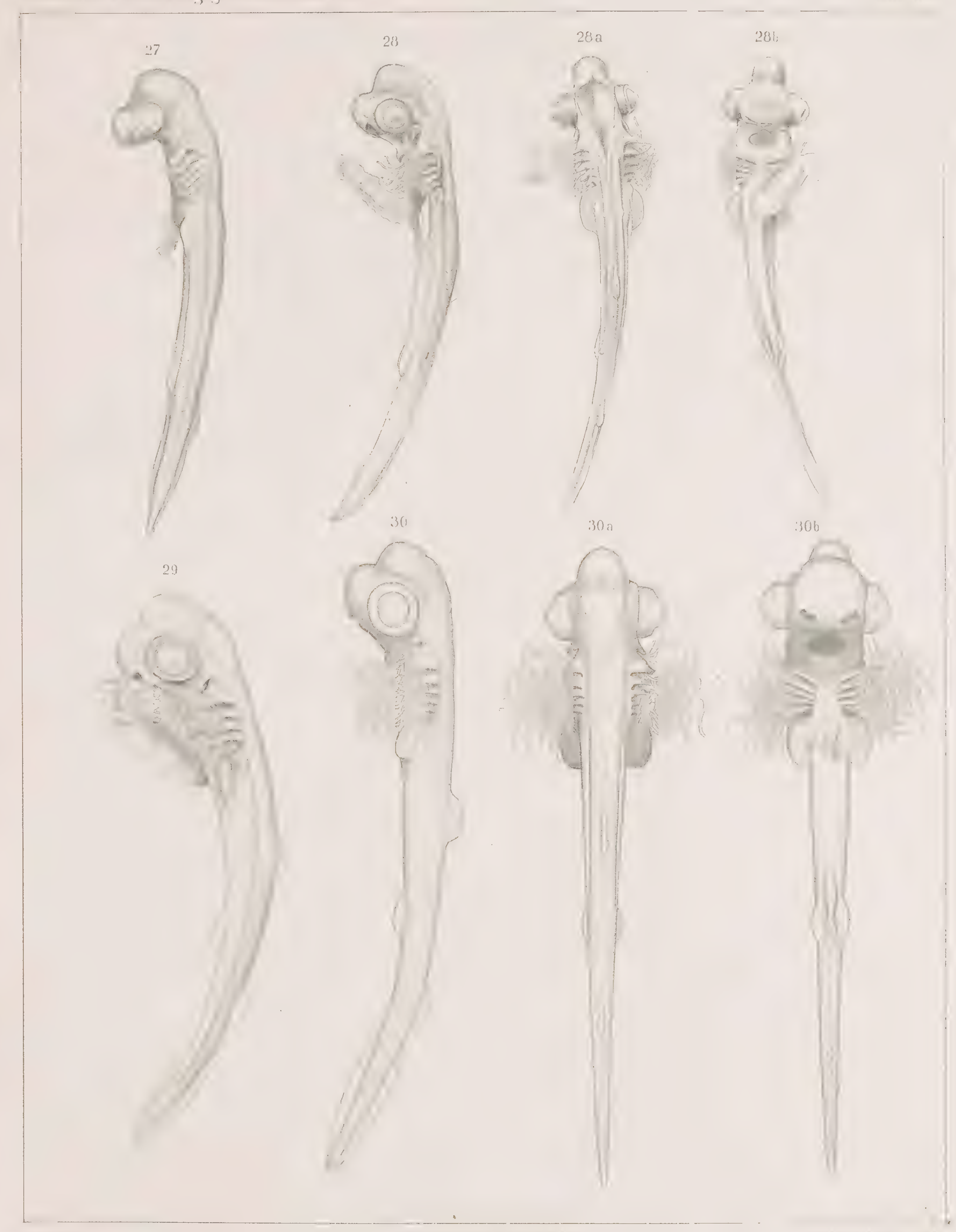
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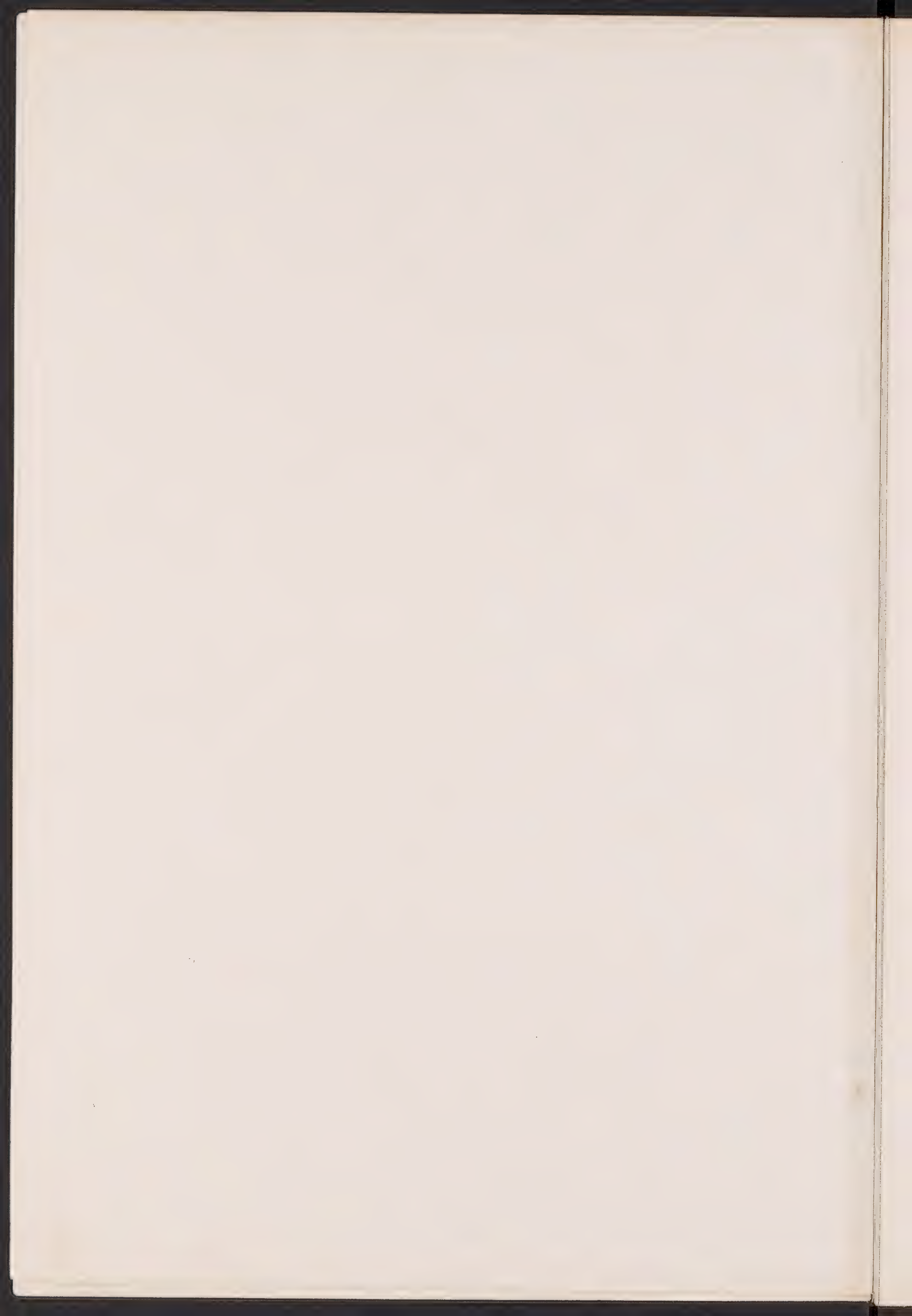


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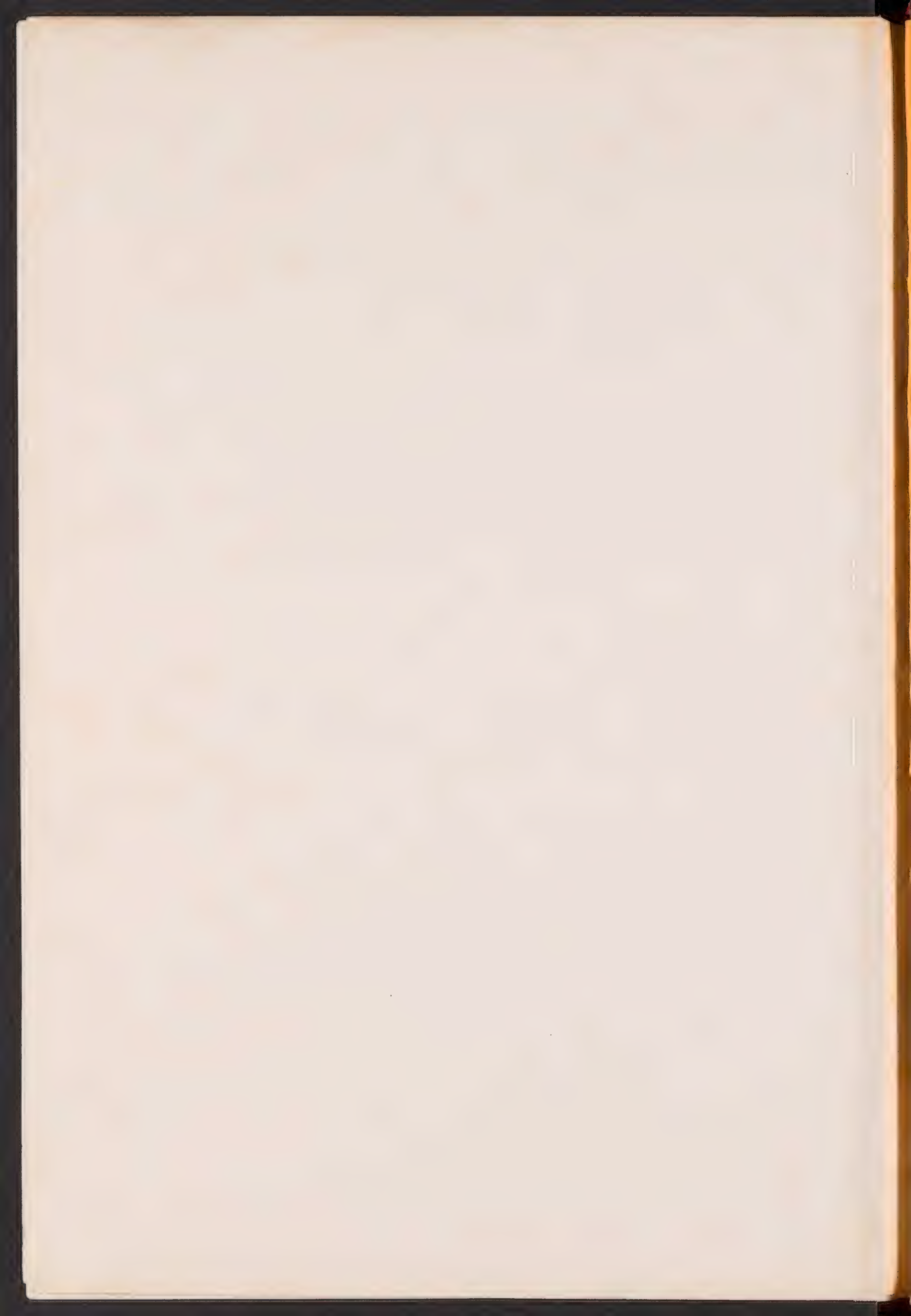




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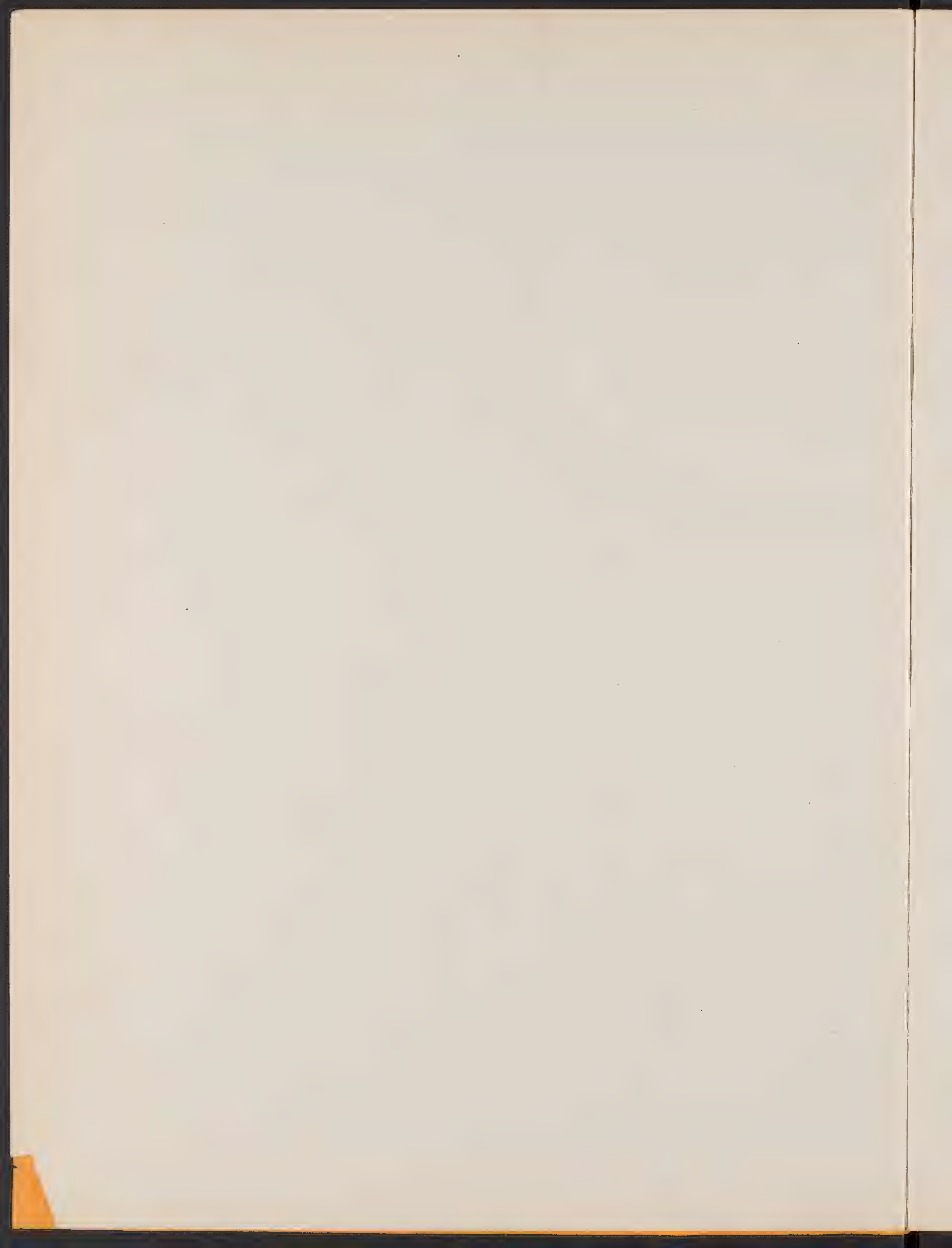


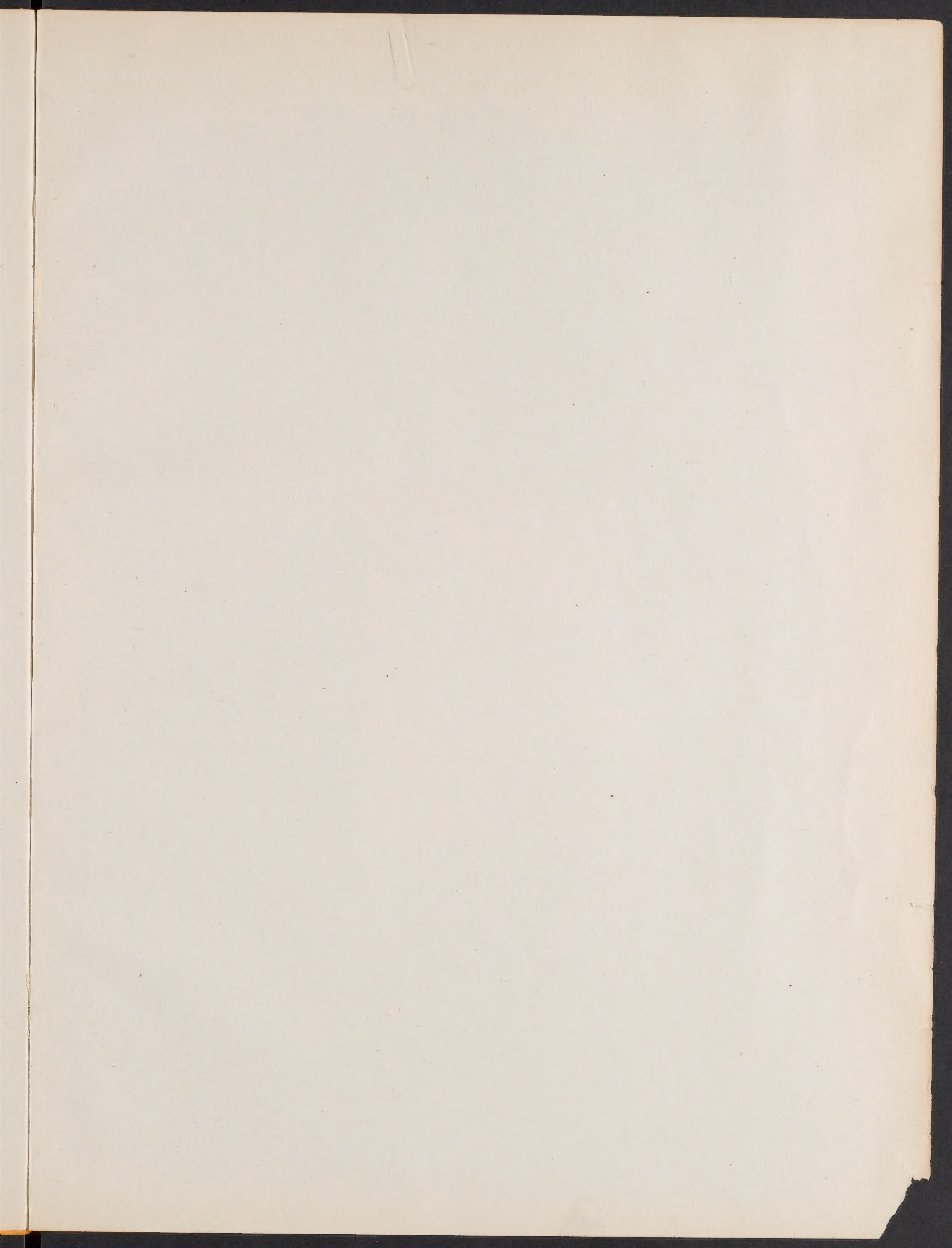

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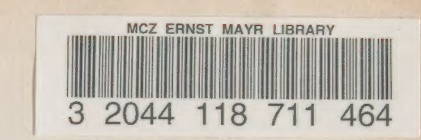


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